PB80-221955

Fugitive Dust from Western Surface Coal Mines

Mathtech, Inc.
Princeton, NJ

Prepared for

Industrial Environmental Research Lab.
Cincinnati, OH

Aug 80

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-600/7-80-158	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Fugitive Dust From Western Surface Coal Mines		5. REPORT DATE August 1980 Issuing Date. 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Frank Cook, Arlo Hendrikson, L. Daniel Maxim and Paul R. Saunders		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Mathtech Division Mathematica, Inc. Princeton, NJ 08540		10. PROGRAM ELEMENT NO. EHE623 11. CONTRACT/GRANT NO. Contact No. 68-03-2477
12. SPONSORING AGENCY NAME AND ADDRESS Energy Pollution Control Division Industrial Environmental Research Laboratory U.S. EPA Cincinnati, Ohio 45268		13. TYPE OF REPORT AND PERIOD COVERED Final 14. SPONSORING AGENCY CODE
15. SUPPLEMENTARY NOTES		

16. ABSTRACT

Field measurement of fugitive dust levels were made 250 to 500 meters downwind of mining activities and areas at four surface coal mines in the Northern Great Plains during three different climatic conditions. Ambient dust levels were also monitored. Wide ranges of temperature, wind speed, wind direction, precipitation, soil moisture, and mining activity levels are represented in the field data.

Statistical data analyses have been extensively employed to examine trends, test hypotheses and explore relationships. Key findings are as follows. Mine-to-mine differences in average total suspended particulates (TSP) levels were significant; the evidence for seasonal differences is weaker but consistant with physical theory and prior judgements. There are indications that snow cover, in particular, is associated with lower TSP values. On the average, downwind TSP levels were 35 percent higher than ambient (upwind) levels, although ambient levels exceeded downwind levels during 29 percent of the sampling periods. Most mining activity levels, except pickup truck operation, were positively correlated with TSP levels, but only the following correlations were significant: dragline activity, coal haulage, on- and off-mine traffic. Overall, wind speed raised to the 0.4 power was the best predictor of TSP levels.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
coal mines dust control air pollution coal dust	Western United States pollution control dust	13B

18. DISTRIBUTION STATEMENT Release unlimited Available from NTIS	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 257
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)

PB80-221955

EPA-600/7-80-158
August 1980

FUGITIVE DUST FROM WESTERN SURFACE COAL MINES

by

Frank Cook, Arlo Hendrikson,
L. Daniel Maxim and Paul R. Saunders
Mathtech Division
Mathematica, Inc.
Princeton, New Jersey 08540

Contract No. 68-03-2477

Project Officer

Edward R. Bates
Energy Pollution Control Division
Industrial Environmental Research Laboratory
Cincinnati, Ohio 45268

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

U. S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF RESEARCH AND DEVELOPMENT
INDUSTRIAL ENVIRONMENTAL RESEARCH LABORATORY
CINCINNATI, OHIO 45268

DISCLAIMER

This report has been reviewed by the Industrial Environmental Research Laboratory-Cincinnati, U.S. Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the U.S. Environmental Protection Agency, nor does mention of trade names or commerical products constitute endorsement or recommendation for use.

FOREWORD

When energy and material resources are extracted, processed, converted, and used, the pollutional impact on our environment and even on our health often requires that new and increasingly more efficient pollution control methods be used. The Industrial Environmental Research Laboratory-Cincinnati (IERL-CI) assists in developing and demonstrating new and improved methodologies that will meet these needs both efficiently and economically.

Total suspended particulate (TSP) levels were measured upwind and downwind of mining and reclamation activities at four western U.S. surface coal mines during three different climatic seasons. Statistical analyses of the resulting data were conducted to identify and explain variability in observed TSP levels.

For further information contact the Energy Pollution Control Division.

David G. Stephan
Director
Industrial Environmental Research Laboratory
Cincinnati

ABSTRACT

Field measurement of fugitive dust levels were made 250 to 500 meters downwind of mining activities and areas at four surface coal mines in the Northern Great Plains during three different climatic conditions. Ambient dust levels were also monitored. Wide ranges of temperature, wind speed, wind direction, precipitation, soil moisture, and mining activity levels are represented in the field data.

Statistical data analyses have been extensively employed to examine trends, test hypotheses and explore relationships. Key findings are as follows. Mine-to-mine differences in average total suspended particulates (TSP) levels were significant; the evidence for seasonal differences is weaker but consistant with physical theory and prior judgements. There are indications that snow cover, in particular, is associated with lower TSP values. On the average, downwind TSP levels were 35 percent higher than ambient (upwind) levels, although ambient levels exceeded downwind levels during 29 percent of the sampling periods. Most mining activity levels, except pickup truck operation, were positively correlated with TSP levels, but only the following correlations were significant: dragline activity, coal haulage, on- and off-mine traffic. Overall, wind speed raised to the 0.4 power was the best predictor of TSP levels.

CONTENTS

Page

Disclaimer ii

Foreword iii

Abstract iv

Figures vii

Tables ix

1. Introduction 1

2. Conclusions 2

3. Recommendations 4

4. Field Conditions and Procedures 5
    - Introduction 5
    - The mines 5
    - The visits 5
    - Methodology of observations 7
    - Sampling plan 7
    - Dust concentrations 11
    - Soil moisture 13
    - Weather conditions 20
    - Mining activities 23
    - Special dust control procedures 26
    - Missing data 27

5. Data Analysis 28
    - Introduction 28
    - Data and assumptions 30
    - ANOVA: beginning of a search for structure 33
    - Numerical estimates of main effects and interaction terms 39
    - The choice of a transformation 48
    - Review of relevant theory 50
    - Application to particulates data 52
    - A return to the question of outliers 57
    - Differences among sampler locations 59

CONTENTS (continued)

Page

Relationship of TSP to activity levels 69
Details of regression results 75
The distribution of particle size 81

Bibliography 83

Appendices

A. Mine Maps 89

B. Coordinate Geometry 103
Point source 103
Line source 106

C. Literature Survey 115
Introduction 115
Emission models 117
Particle size and deposition rates 130
Dispersion models 136

D. Field Data 142

FIGURES

Number Page

1 Plot of GAU^{-1} (TSP) versus log of TSP value confirms long tail distribution 15

2 Shape of likelihood surface for selecting transformation 54

3 Scattergram (log-log scales) of TSP for ambient samplers: data sets 1 and 2 with outliers deleted 68

A-1 Legend for mine maps 90

A-2 Map for mine 1, visit 1 91

A-3 Map for mine 1, visit 2 92

A-4 Map for mine 1, visit 3 93

A-5 Map for mine 2, visit 1 94

A-6 Map for mine 2, visit 2 95

A-7 Map for mine 2, visit 3 96

A-8 Map for mine 3, visit 1 97

A-9 Map for mine 3, visit 2 98

A-10 Map for mine 3, visit 3 99

A-11 Map for mine 4, visit 1 100

A-12 Map for mine 4, visit 2 101

A-13 Map for mine 4, visit 3 102

B-1 Coordinate geometry for a point source 104

B-2 Sampler distance from plume centerline 107

FIGURES (continued)

Number Page

B-3 Distance from line source to sampler 108

B-4 Skewed area source geometry 111

C-1 Fine particles are reflected 139

C-2 Tilted plume hypothesis 141

TABLES

Number Page

1 Selected Features of Mines Visited (After Axetell) 6

2 Mine Visits and Dates 8

3 Frequency Distribution of TSP Values 14

4 Minimum, Maximum, and Mean for Soil Moisture 17

5 Moisture Data and Associated Computations for Mine 1, Visit 1 18

6 ANOVA Computations for Moisture Data, Mine 1, Visit 1 19

7 Minimum, Maximum, and Average Values for Wind Speed by Mine and Visit 21

8 Minimum, Maximum, and Average Values for Wind Direction 21

9 Minimum, Maximum, and Mean for Temperature 22

10 Precipitation and Snow Cover Data 22

11 Mean and Extreme Stability Class 24

12 Activity Summary 25

13 Raw Data and Estimates of Missing Data for First Seven Shifts 31

14 Analysis of Variance Tableau for Exploratory Analysis ANOVA 1: Mines and Locations Random, Seasons Fixed 35

15 Analysis of Variance Tableau for Exploratory Analysis ANOVA 2: Mines, Seasons, and Locations Random 36

TABLES (continued)

Number Page

16 Ancillary Tables - Sums of Raw Data 37

17 Analysis of Variance Computations 38

18 Analysis of Variance Tableau: Mines, Locations Random and Seasons Fixed 40

19 Analysis of Variance Tableau: Mines, Seasons, and Locations Random 41

20 Components of Variance Estimates: Mines and Locations Random, Seasons Fixed 42

21 Components of Variance Estimates: Mines, Seasons and Locations Random 43

22 Numerical Estimates of Main Effects and Interaction Terms 44

23 Mean Values for "What If" Analysis 47

24 Consequences of Deleting Data From Mine 1 Season 3 Untransformed Data - All Units in $\mu g/m^3$ 49

25 Numerical Search to Select Optimal Transformation . . 53

26 Analysis of Variance Computations: Three Candidate Outliers Deleted, Transformed Data ($\theta = 0.0$) 55

27 Analysis of Variance Tableau: Mines, Locations Random and Seasons Fixed: Three Candidate Outliers Deleted, Transformed Data ($\theta = 0.0$) 56

28 Analysis of Variance Computations: Three Candidate Outliers Deleted, Transformed Data ($\theta = 0.0$) 58

TABLES (continued)

Number		Page
29	Analysis of Variance Tableau: Mines, Locations, Random and Seasons Fixed: Three Candidate Outliers Deleted, Transformed Data ($\theta = 0.0$)	60
30	Upwind and Downwind Sampler Analysis Data Set 1 . . .	62
31	Paired t Test on Upwind Versus Downwind Sampler Locations, Data Set 1, (Transformed Observations) .	62
32	Upwind and Downwind Sampler Analysis Data Set 2 . . .	64
33	Paired t Test on Upwind Versus Downwind Sampler Locations, Data Set 2, (Transformed Observations) .	64
34	Summary of Results for Upwind Versus Downwind Analysis: Transformed Data	66
35	Table of Activity Numbers, Definitions for Regression Analysis	70
36	Means and Standard Deviations for Regression Activity Analysis (All Variables Transformed as Natural Logarithms)	73
37	Simple Correlation Coefficients for Activity Analysis	74
38	On the Trail of Multicollinearity: Simple Correlation Coefficients Between Dummy Variables for Mines and Trips and Activity Variables	77
39	A Summary of Selected Regression Results	78
40	Regression Statistics for Model Selection	80
41	Regression Output for Combined Activity and Site- and Season-Specific Analysis	82
C-1	Soil Properties (Agricultural Tilling)	126
C-2	Estimated Vs. Actual Emissions (Agricultural Tilling)	127

SECTION 1

INTRODUCTION

Over the years 1969 to 1977 production of coal by the surface mining method in the western United States has grown at a compound annual growth rate of 27%. Annual production for a seven-state western area, which was approximately 110 million tons in 1977, was only 16 million tons in 1969. (McNeal *et al.* 1978.) Continued growth is anticipated.

Most strippable western coal is located in semi-arid, high plains areas characterized by sparse vegetation, erodable soils, and high winds. High ambient dust levels are a combined result of these factors. Disturbance of land by surface coal mining may worsen these dust conditions.

There exist theoretical models for use in estimating the dispersion patterns for particulate matter emanating from a point source, such as a powerplant stack. More recently, attempts have been made to model emission, dispersion, and deposition of fugitive dust from point and non-point sources typical of those from western surface coal mines. To date, however, there have been few attempts to apply statistical techniques to determine empirical relationships between suspended particulate levels in mining areas and explanatory variables, such as mining activity levels and meteorological variables. This study employs such techniques to examine the effects on air quality of mine operations under various meteorological and operational conditions.

TYPING GUIDE SHEET

SECTION 2

CONCLUSIONS

The following conclusions were derived from statistical analysis of suspended particulate data gathered using four high-volume air samplers at four western surface coal mines on three trips during the periods late May to late June, 1977, early November, 1977 to early December, 1977, and late December, 1977 to early February, 1978. Roughly 80 percent of the total suspended particulate values were obtained 250 to 500 meters downwind of mining areas and activities, the other 20 percent being upwind or "ambient". Prevailing winds during sampling periods were westerly, averaging 5 to 14 miles per hour, and gusting to 35 miles per hour. Ambient temperature values averaged between -20 and 62 degrees Farenheit. Sampling took place during dry periods as well as during periods of rain and snow.

Findings and conclusions are summarized below.

1. The average TSP level for all samplers over all mines and all trips was 157 micrograms per cubic meter ($\mu g/m^3$). (Summaries of the meteorological conditions under which these were obtained can be found on pg. 24 *et seq.*) Percentile values were the following:

Percent of Observations Below TSP Value	TSP Value ($\mu g/m^3$)
2.5	22
50.0	110
97.5	620

The average lies above the median value of 110 because readings below the average were more frequent; that is, the distribution of TSP values is skewed to the right.

2. Mine-to-mine differences in average TSP levels were highly significant. Mine averages ranged between 115 and 234 $\mu g/m^3$. But site-specific differences other than the types and levels of mining activities were more important in explaining TSP variability than were the activity levels themselves.

EPA-287 (Cin.) (4/75)

3. There is evidence to suggest that there are seasonal differences in average TSP levels. Such evidence falls short of unequivocal proof, however.

4. Differences in average TSP levels among samplers were significant. On average, downwind TSP levels exceeded ambient levels by 35 percent. (The 95 percent confidence interval on this difference is 8 to 64 percent.) On 29 percent of the observations, however, upwind or ambient TSP levels exceeded those of all three downwind samplers. This reflects the complexity of transport phenomena. The level of dust not due to mining activities evidently at times is higher upwind than downwind.

5. All mining activity levels correlated with TSP levels in the positive direction, except precipitation (expected) and pickup truck traffic at the mines (unexpected). Possible causes of the unexpected negative correlation are discussed in Section 5. Statistically significant correlation occurred between TSP levels and the following variables:

   - Wind speed
   - Frequency of dragline operation
   - Frequency of coal haulage from the pit
   - Frequency of pickup truck traffic at the mine
   - Amount of traffic on unpaved public road adjacent to mine sites.

   Of these, wind speed is the strongest predictor of TSP levels.

6. The relationship between TSP level and explanatory variables, derived from statistical analysis of data pooled over all mines, field trips, and samplers, is:

$$\overline{TSP} = 30.3\ Q_1^{0.13}\ Q_2^{0.10}\ Q_8^{0.10}\ S^{0.40}$$

where $\overline{TSP}$ = average TSP ($\mu g/m^3$)

Q_1 = dragline operating time per shift (hours)
Q_2 = number of coal haulage truck trips per shift
Q_8 = number of vehicles driven past the mine on unpaved public roads, per shift
S = wind speed (mph)

SECTION 3

RECOMMENDATIONS

It is recommended that a large-scale, long-term experimental program be conducted to develop and validate empirical relationships between total suspended particulate levels in western surface coal mining areas and explanatory variables which measure the characteristics of the real dust sources found at such mines. Total suspended particulate levels should be measured at two or more mines over a period long enough to ensure that wide range of mining and meteorological variables are observed. Empirical results should be systematically compared to those estimated using published emission factors and dispersion/deposition assumptions.

SECTION 4

FIELD CONDITIONS AND PROCEDURES

INTRODUCTION

This chapter details the measurement devices, field procedures and relevant limitations of the data collection effort.

This chapter also contains frequency distributions and other relevant statistics calculated from the raw data which is useful for data interpretation.

In brief, the data collection plan included three visits at different seasons to each of four surface mines. Four high volume air samplers were used to measure dust concentrations during these visits. Additional data was collected on soil moisture, weather conditions and activity levels of various mining or mining related operations. These data are candidate explanatory factors to describe the observed variability in dust concentrations.

THE MINES

Observations were taken at several sites within four mines. The mines were selected from among nine that had been surveyed on a previous EPA contract (No. 68-03-2226). Willingness of mine operators to permit dust measurements to be taken was an important selection criterion.

Table 1 identifies the region in which the mines were located and presents a brief description of the topography, vegetative cover and soil type at each mine. Axetell (1978 p.6) found that estimates of fugitive dust emissions for a particular mining operation can vary widely among mines. To facilitate comparison, the code-letter of the most similar mine in Axetell's study appears in Table 1.

Mine maps drawn from aerial photographs are contained in Appendix A. These maps show the location of mining activities, samplers, soil moisture observations, the weather station and unvegetated areas for each visit.

THE VISITS

To help ensure that a wide variety of operating conditions was observed and, additionally, to study the effect of seasons of year on

TABLE 1. SELECTED FEATURES OF MINES VISITED (AFTER AXETELL)

Mine	Location	Terrain	Vegetative cover	Soil type (surface)	Mine cover
1	Eastern Montana	Rolling	Grassland	Clayey	E
2	Central North Dakota	Semi-rugged	Sagebrush	Loamy	D
3	Central North Dakota	Semi-rugged	Sagebrush	Loamy	D
4	Eastern Wyoming	Rolling	Grassland	Sandy, clayey	C

particulates values, three visits were made to each mine. The field team visited each mining operation sequentially. The first round of visits took place in the spring of 1977. The second took place that fall, and the third and final visit was made during the winter of 1977-78. Table 2 provides the dates for each of the visits. Visit durations ranged from 3 days to one week.

METHODOLOGY OF OBSERVATION

Variables measured during the mine visits included dust concentrations, meteorological variables such as wind speed and direction, temperature and precipitation, soil moisture and finally quantitative data on the pattern and intensity of mining activities. Additional data gathering included the acquisition of aerial photographs from which maps could be drawn. The collection plan is described below.

SAMPLING PLAN

Several factors must be considered in the design of a sampling plan for measuring the atmospheric concentration of particulates. Some of these are:

(1) Emissions sources to be measured.
(2) Direction of the air sampler from the source.
(3) Distance of the air sampler from the source.
(4) Duration of sampling interval.

Some options for sampler use during a given day are: (a) one 24-hour sample, (b) two 12-hours samples, and (c) three 8-hour samples. It was determined that air samplers be operated for eight-hour periods between filter changes. Three reasons for the choice of this period are:

(i) More data is available for estimating the parameters in a model when shorter sampling periods are used.

(ii) Wind speed and wind direction are so variable during a 24-hour period that one of the 8-hour periods can be expected to account for the majority of the dust collected from the mine. By using shorter periods, more accurate estimates can be made of the dust arising from different wind directions and wind speeds.

(iii) Dust emissions are dependent on mining activities, which vary with 8-hour shifts. Thus, the sampling periods should match as closely as possible changes in shifts. This is particularly true for samplers downwind from sources where changes in activity take place at the end of a shift.

TABLE 2. MINE VISITS AND DATES

Mine	Visit	Date	
		From	To
1	1	24 May 1977	27 May 1977
	2	21 November 1977	23 November 1977
	3	19 December 1977	21 December 1977
2	1	8 June 1977	11 June 1977
	2	8 November 1977	11 November 1977
	3	11 January 1978	14 January 1978
3	1	8 June 1977	15 June 1977
	2	15 November 1977	18 November 1977
	3	17 January 1978	29 January 1978
4	1	21 June 1977	24 June 1977
	2	30 November 1977	3 December 1977
	3	30 January 1978	2 February 1978

The goal is to place the monitors in such a manner that a profile of the concentration of particulates can be obtained. Sampler locations and sampling intervals are restricted to areas and intervals such that sufficient amounts of particulates will be collected to give reliable estimates of the air concentration at the receptor point. We first consider sampling intervals.

The hi-vol samplers have a sampling rate of 20 c.f.m. or 34 meter^3/hr. If the air concentration for particulates of a size collected by one of the four filters is c $\mu g/m^3$ then during a period of eight hours, a total of (2.72×10^{-4}) c grams will be collected in the filter. Thus, if the concentration is 37 $\mu g/m^3$, 0.01 grams will be collected in an eight-hour period.

The value 37 $\mu g/m^3$ is representative of the annual average total suspended particulates in a nonurban atmosphere. The maximum concentration may exceed this value by a factor of 10. To obtain reasonable amounts of dust, the air samplers should be located close to major sources of dust from the mine. Mathtech determined that samplers should be placed within a maximum distance of 1000 meters from a source in order to measure emissions. Contributions to air quality at remote distances could be estimated through dispersion/deposition modeling.

The placement of samplers is dependent on the predominant wind direction. Although the air samplers are portable, it was not practical to move the air samplers more than once every 24 hours. Because wind direction is variable within 24 hour periods, sampler locations were approximated prior to the sampling period by determining the predominant wind direction for that season.

The following is an outline of the air sampling program as conducted by Hittman Associates' field team.

Pretrip Requirements

A. Check out and test high volume air samplers, generators, and weather station to insure workability. Order required replacement and spare parts. Each high volume air sampler should have at least one extra set of brushes for the motor since this part is known to wear out rather rapidly.

B. For ease of handling after sampling, each filter will be placed in a suitable plastic bag, and the bag will be sealed. To obtain pre-sampling weights of bags and filters:

   1) Number each filter and corresponding plastic bag in the lower right-hand corner.

2) Weigh each filter and corresponding plastic bag together to the nearest 0.0001 gram.

3) Place filter in corresponding bag and seal.

Sampling Procedure

A. Sample each mine in consecutive order.

B. Set up four high volume air samplers and generators at each mine at locations designated by Mathtech.

C. Change filters at designated eight-hour intervals.

D. When each filter is removed, place it in its like-numbered plastic bag and seal.

E. Record filter number, location, time interval, data, and other pertinent information about the filter on forms to be provided.

F. Record activity at mine at specified intervals on mine activity data sheets to be provided by Mathtech.

G. Change locations of high volume samplers on a daily basis to new locations as requested by Mathtech.

Post Sampling Analysis

A. Open plastic bags and let sit at ambient conditions for 24 hours.

B. Weigh bag and filter to the nearest 0.0001 gram.

C. Report difference in weight on forms provided.

A somewhat modified version of this plan was put into practice. One imporant modification was to the sampler placement design. Ownership of the surrounding land, topography, and accessibility of samplers to refueling trucks limited the area in which samplers were placed. Selection of sites could not be made solely on the basis of predominent wind direction and activity location. In addition, the variability of the wind direction argued for a more ad hoc placement in order to obtain an ambient (upwind) reading.

Originally, one visit per season was planned. Delays in securing permission to enter mine premises to conduct the measurements delayed the spring visit until June. It was decided that this visit should serve as a combined spring-summer visit.

The modified plan as executed is described in detail below.

DUST CONCENTRATIONS

Dust concentrations were measured with General Metal Works GMWL 2000 high volume air samplers. These draw in particulate matter with diameters under 100 microns and pass them through a graded series of paper filters. In this experiment, the filters trapped particles in the size ranges of 0-1.1 microns, 1.1-2.0 microns, 2.0-3.3 microns, 3.3-7.0 microns and 7.0 microns or larger. The samplers were driven by small gasoline generators which were positioned so that their exhaust would not enter the sampler's intake.

Further details of the sampling procedures are given below:

(1) The filters used for this study were glass fiber discs (Anderson head) and rectangles (backup) chosen for their light tare weight and non-hygroscopic properties.

(2) Preparation of filters for field sampling - Anderson head and backup filters and bags were numbered with a marking pen and were allowed to dry overnight in plastic garbage sacks to prevent contamination prior to weighing. Filters and matching bags were weighed together on a Mettler balance, rated accurate to 0.0001 grams. A zero adjust check was made every 25-30 samples to insure accurate weights. Each filter and bag was handled, at all times, with plastic surgical gloves to prevent dirt and oil contamination, and was returned immediately after weighing, in a sandwich arrangement, to its respective plastic sack. The sacks were placed in cardboard boxes to prevent rubbing between filters and bags, and the boxes, in turn, were placed in a footlocker to cut down on dust settling on the outside of the sacks. The sacks remained sealed except during brief periods while changing filters.

(3) Description of sampler operation and procedure - Generators were placed downwind from the sampler at a distance of 25 ft. (one extension cord length). Each sampler consisted of a General Metal Works hi-volume air sampler combined with an Anderson 2000 particle sizing sampler, calibrated for 20 cfm. use. The operations manual provides additional features of this device. The areas around the sampler intake and the heads themselves were cleaned with acetone prior to each field trip. Heads were kept in plastic bags to insure cleanliness while in transit.

All hi-vols were equipped with pressure recorder clocks. In the event a generator would cease operation, these clocks recorded the time period during which the samplers operated.

To supply the generator with sufficient gas to run for an 8 hour period, a hose to a small metal barrel was attached to the generator tank and gas was dripped into the generator tank at a slow rate.

The Anderson head was loaded with filters in the back of a pickup truck protected by a fiberglass camper shell. All operations involving contact with filter media were conducted while wearing plastic gloves. The Anderson head and backup filter were then transported to the sampler and fastened in place.

Calibration of the Anderson head/hi-vol unit to 20 cfm. was conducted as follows. First the high vol was turned on until air flow stabilized (usually a few seconds). Then an oil filled manometer (described in the operating manual), read in inches of water, was attached to a pin hole orifice protruding from the lowest stage of the Anderson head. A laboratory calibration curve provided for each head was used to compensate for elevation differences. The elevations for each sampler were obtained from contour maps in the mine office. The manometer reading, thus obtained, was used when regulating air flow thru the samplers.

With the manometer attached to the Anderson head, the air flow of the sampler was controlled by one or two voltage regulating "pots". These pots were manipulated until the reading on the manometer matched the correct reading determined by the curves. The manometer is then removed - the operation completed. (Note: A constant flow of 20 cfm. is maintained by a probe located between the filter assembly and the motor/blower unit.)

(4) Storage of samples - Each filter had its corresponding plastic bag. The collected sample and filter were placed in this bag and sealed to prevent contamination and escape of sample. These bags were stored in a large plastic sack for the duration of the field trip and remained in the sack until they were weighed.

(5) Obtaining final filter weights - The plastic sacks containing samples from each trip were transported to the analytical balance for weighing. The same scales were used throughout the study when measuring before and after weights. Again, each bag was handled and weighed while wearing plastic gloves. The zero adjust on the scales was monitored every 25-30 samples as before.

Four samplers were available for deployment on each visit. They were placed at locations determined by the prevailing wind directions at each mine during each season of observation. Naturally, these locations changed from visit to visit. The measurement plan called for one sampler to be placed upwind of all mining activities to measure ambient dust concentrations, though variability of wind direction sometimes placed the "ambient" sampler downwind of some of the mining operations. Contaminated "ambient" sampler readings were selectively excluded from analysis, as described in Section 5. The other samplers were placed downwind of major dust sources such as draglines, blasting, and spoil piles at distances ranging from 250 to 500 meters.

The observation plan called for one set of concentration measures for each eight hour working shift at the mine. The samplers were allowed to run for periods varying from one and one-half to six hours.

At the end of each observation period the filters were removed and weighed and the accumulated dust converted to a concentration in units of micrograms per cubic meter.

The lengths of sampling periods were chosen to ensure that the observed concentrations would be representative of typical mine conditions. One consequence of the longer sampling periods was that the wind would sometimes shift direction during the sampling period. Some changes in direction caused different samplers to be upwind of mining activities at different times within the sampling period. When this occurred, no measurement of the ambient level of concentration was possible.

The number of observations for which there was clearly an ambient sampler was reduced by a number of other factors. Wind direction, for example, was measured hourly. During some hours the direction varied enough that no meaningful single figure could be assigned. At times, the wind was calm. The Gaussian plume dispersion model predicts that when the wind is calm dust emissions remain at their sources and the concentrations build to infinity. In reality the Brownian motion of the air molecules and thermal convection currents will cause the dust to disperse, but this has not been modeled and one cannot determine which if any of the samplers receive dust from on-mine sources. For some wind directions, none of the four samplers was upwind.

Particulate values in each size range were aggregated to give total suspended particulates (TSP). TSP values over all samples during all shifts at all visits to all mines averaged 157 micrograms per cubic meter and ranged from 10 (the smallest observed) to 1,600 (the largest observed). Approximately 95% of the observations fell beneath 450 $\mu g/m^3$. Table 3 shows the frequency distribution of TSP values including cumulative percentage figures and the standardized normal variate (GAU^{-1}) corresponding to the empirical cumulative distribution function. (As can be seen, the overall distribution is asymmetrical, being skewed to the right.) The standardized normal variate gives the values which would occur in the center of each interval *if* TSP had a Gaussian (normal) distribution with mean zero and the observed standard deviation. A graph of these values versus the actual values would yield a straight line if TSP had a normal distribution. Figure 1, a plot of log TSP vs. GAU^{-1} (TSP), indicates that the distribution of TSP values is instead roughly log-normal. Analyses reported in Section 5 of this report show that the residual variance in TSP after removing systematic effects are indeed log-normal, and that this transformation stabilizes the residual variance.

SOIL MOISTURE

Soil moisture as percent of total weight was recorded at locations designed to reflect diverse soil conditions: haul roads, the pit and bench, off-mine roads, topsoil or spoil piles, areas of contouring or reclamation, and the surrounding landscape. (It should

TABLE 3. FREQUENCY DISTRIBUTION OF TSP VALUES

TSP ($\mu g/cm^{-3}$)		Number of observations in this interval	% observations in interval	Cumulative %	GAU^{-1}	TSP ($\mu g/cm^{-3}$)		Number of observations in this interval	% observations in interval	Cumulative %	GAU^{-1}
From	To					From	To				
0	19.9	5	1.69	1.69	-2.12	280	299.9	5	1.69	91.50	1.37
20	39.9	20	6.78	8.47	-1.37	300	349.9	8	2.71	94.21	1.57
40	59.9	22	7.46	15.93	- .99	350	399.9	3	1.02	95.23	1.67
60	79.9	36	12.20	28.13	- .58	400	449.9	1	0.34	95.57	1.70
80	99.9	48	16.27	44.40	- .14	450	499.9	1	0.34	95.91	1.74
100	119.9	35	11.86	56.26	.16	500	549.9	1	0.34	96.25	1.78
120	139.9	30	10.17	66.43	.43	550	599.9	2	0.68	96.93	1.87
140	159.9	21	7.12	73.55	.63	600	649.9	2	0.68	97.61	1.98
160	179.9	13	4.41	77.96	.77	650	699.9	0	0.00	97.61	1.98
180	199.9	9	3.05	81.01	.88	700	749.9	1	0.34	97.95	2.04
200	219.9	9	3.05	84.06	1.00	750	999.9	3	1.02	98.97	2.32
220	239.9	5	1.69	85.75	1.07	1000	1249.9	0	0.00	98.97	2.32
240	259.9	7	2.37	88.12	1.18	1250	1499.9	1	0.34	99.31	2.46
260	279.9	5	1.69	89.81	1.28	1500	up	2	0.68	99.99	

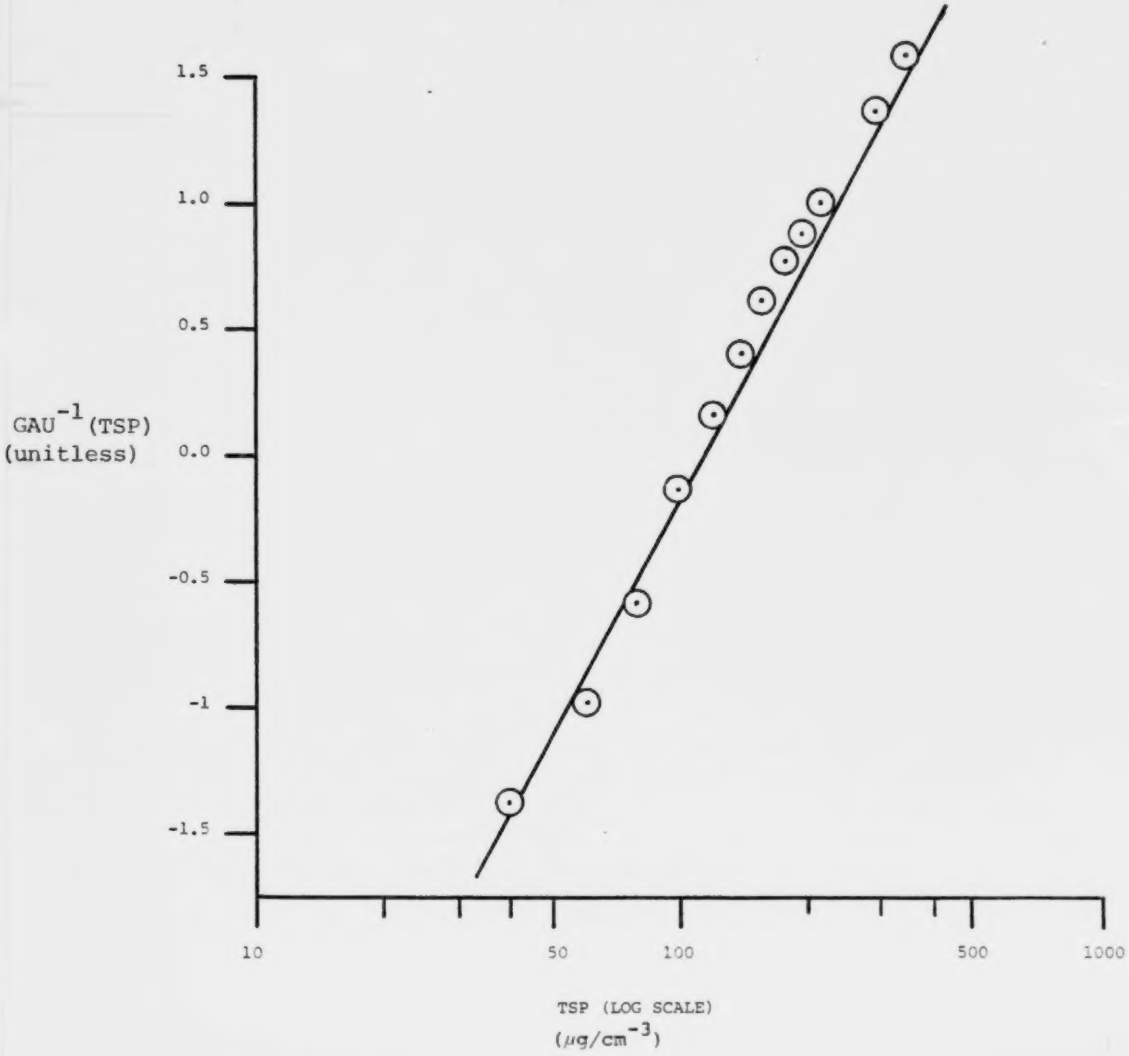


Figure 1. Plot of GAU^{-1} (TSP) versus log of TSP value confirms long tail distribution.

be noted that haul road watering was observed only at mine 2 on the first visit.) Measurements were taken at each location for each shift. Table 4 shows minimum, maximum and mean soil moisture values for all visits where such data were collected. Moisture figures for all locations showed significant temporal variation within visits. Table 5, which presents the technical details of the analysis described below, shows soil moisture data collected in seven shifts at the first visit to mine number 3. The sampling locations included a spoil pile, topsoil stripping, haul roads, and a topsoil pile.

An analysis of variance was performed on the soil moisture data which sought to break down the variability into an effect due to sample location, an effect due to shift (temporal variability), and an error term. Specifically, suppose that:

$$y_{ij} = \mu + \xi_i + \eta_j + \epsilon_{ij} \tag{1}$$

where y_{ij} = value of soil moisture from location i collected during shift j

μ = overall mean of the observations

ξ_i = effect due to ith location

η_j = effect due to jth shift (time)

ϵ_{ij} = error of observation ij.

The average soil moisture for the first seven shifts of this visit, u, was 13.3%. Mean moisture levels across all locations, ($\bar{y}_{\cdot j}$), ranged from 9.12% for shift seven to 19.46% in shift six. This corresponds to a range of effects n_j of from -4.26% to 6.08%. Mean moisture levels across all shifts for a given location, ($\bar{y}_{i\cdot}$), ranged from 11.74% for the topsoil pile to 15.97% for the spoil pile. This corresponds to a smaller range of effects of from -1.64% to 2.59%. As can be seen, the temporal effects (column effect) are larger than the spatial effects (row effects). A complete analysis of variance (ANOVA) for these data is shown in Table 6. Though both spatial and temporal variability is statistically signficant, the components of variance analysis indicates that temporal variability is much larger than spatial variability. That is, moisture data from different locations collected at the same time period are much more alike than moisture data collected at the same location over different time periods. This same trend was observed for all visits to all mines. For this reason, moisture data from various locations were pooled to form an average value, taken to be representative of the shift in which measured.

A final remark in connection with soil moisture data is that one pronounced correlation exists between soil moisture and visit. On the third visit, the ground at all three mines was frozen. An analysis of the effect of this and other soil-moisture conditions on dust levels can be found in Section 5.

TABLE 4. MINIMUM, MAXIMUM, AND MEAN FOR SOIL MOISTURE

Mine	Visit	Min. moisture (% weight)	Max. moisture (% weight)	Mean moisture (% weight)
1	2	2.4	9.9	4.6
2	1	1.0	20.7	11.5
	2	1.5	25.2	6.4
3	1	5.3	20.6	13.3
	2	.7	19.8	5.5
4	1	1.2	9.8	4.7
	2	.6	22.9	7.0

TABLE 5. MOISTURE DATA AND ASSOCIATION COMPUTATIONS FOR MINE 1 TRIP 1

	Shift							Subtotal	Mean	Row effect
Location	1	2	3	4	5	6	7	$T_{i\cdot}$	$\bar{y}_{i\cdot}$	$\xi_i = \bar{y}_{i\cdot} - \bar{y}$
Spoils pile	11.7	14.8	12.8	17.7	20.6	20.5	13.7	111.8	15.97	2.59
Topsoil stripping	8.1	8.0	10.5	19.9	17.4	19.0	6.7	89.6	12.80	-.58
Haul Road 1	11.8	9.3	7.1	18.3	15.9	17.8	7.7	87.9	12.56	-.82
Haul Road 2	12.2	11.4	10.3	17.1	18.2	20.7	6.9	96.8	13.83	.45
Topsoil pile	5.3	8.6	7.6	12.6	18.2	19.3	10.6	82.2	11.74	-1.64
Subtotal $T_{\cdot j}$	49.1	52.1	48.3	85.6	90.3	97.3	45.6	468.30=T		
Mean $\bar{y}_{\cdot j}$	9.82	10.42	9.66	17.12	18.06	19.46	9.12	13.38=$\bar{y}$		
Column effect $n_j = \bar{y}_{\cdot j} - \bar{y}$	-3.56	-2.96	-3.72	3.74	4.68	6.08	-4.26			

Ancillary Quantities

$$\frac{T^2}{N} = 6265.85$$

$$\Sigma_j \frac{T_{\cdot j}^{\;2}}{5} = 6897.24$$

$$\Sigma_i \frac{T_{i\cdot}^{\;2}}{7} = 6340.13$$

$$\Sigma_{ij}\, y_{ij}^{\;2} = 7069.15$$

Shifts:
1,4,7 - 11PM to 7AM
2,5 - 7AM to 3PM
3,6 - 3PM to 11PM

TABLE 6. ANOVA COMPUTATIONS FOR MOISTURE DATA MINE 1 TRIP 1

Source of estimate	Sum of squares	Degrees of freedom	Average value of mean square	Computed F statistic	Components of variance estimate
Among mine locations	$S_i = q\Sigma_i(\overline{y}_{i.} - \overline{y})^2$ 74.28	$p-1$ 4	$\sigma^2 + q\sigma_\xi^2$ 18.570	4.56*	$\sigma_\xi^2 = 2.07$ $\sigma_\xi = 1.44$
Among shifts	$S_j = p\Sigma_j(\overline{y}_{.j} - \overline{y})^2$ 631.39	$q-1$ 6	$\sigma^2 + p\sigma_n^2$ 105.232	25.87*	$\sigma_n^2 = 20.23$ $\sigma_n = 4.50$
Interaction (error)	$S_{ij} = \Sigma_{ij}(y_{ij} - \overline{y}_{i.} - \overline{y}_{.j} + \overline{y})^2$ 97.63	$(p-1)(q-1)$ 24	σ^2 4.068		$\sigma = 2.02$
Total	$S = \Sigma_{ij}(y_{ij} - \overline{y})^2$ 803.3	$N-1$ 34			

*Denotes significant difference at 95% level.

A non-technical summary of this statistical analysis begins on page 13.

WEATHER CONDITIONS

A mechanical weather station built by Meterology Research, Inc. monitored wind speed, wind direction, temperature and precipitation at each site. The manufacturer certifies the readings to be accurate between .75 and 125 mph., and -60° to 120°F. The weather station drove a chart recorder from which readings were taken on an hourly basis. The portable weather station sites were chosen mainly on the basis of topography. High, extensive flat land was preferable because winds blowing from any direction would not be affected by barriers, and would more truly represent the conditions at the mine site. The station was oriented to true north by aligning precut notches on the base of the station with a compass reading (magnetic declination corrected). Summary weather data on wind speed, wind direction, temperature, precipitation and atmospheric stability is presented in Tables 7-11.

Table 7 lists the minimum, maximum and average wind speed observed at each mine during each visit. The speeds range from calm to a maximum of 34.5 miles per hour, and average about nine miles per hour. No clear-cut relations between wind speed and mines or visits emerge. Three of the four mines show different orderings of wind speed over visit - the widest spread possible among three visits. Similarly, no one mine had higher wind speeds throughout. It is apparent that multicollinearity did not occur between wind speed and mine or visit.

Wind direction varied considerably at each mine within each visit, as Table 8 demonstrates. When the minimum and maximum angles are close, the swing frequently occurred the "long way around", that is a more than 180° shift. This variability need not reflect gradual changes. Wind direction shifted by as much as 165° during the course of a four-hour sampling period. During some hours the variability was sufficiently great that no direction could be assigned. No direction was assigned to hours when the wind was calm.

Temperatures, of course, have a strong seasonal dependence. The highest temperatures occurred during the spring visits. Temperatures in the fall and winter visits were closer than between the fall and spring visits. Table 9 presents minimum, maximum and mean temperature values for the various visits.

Snow cover and precipitation data is shown in Table 10. All of the mines lay under a substantial snow cover during the third visit. During the second visit, mines one and four had snow, although the cover at mine four was melting the last day of the visit.

Mine 2 clearly experienced the most frequent precipitation. This appears to have been a random occurrence. Mine 3, physically proximate and studied only a few days later on each round of visits, shows much less precipitation. Mine 4 appears the driest on each visit. At each mine, the winter trip saw the greatest frequency of precipitation.

TABLE 7. MINIMUM, MAXIMUM, AND AVERAGE VALUES FOR WIND SPEED BY MINE AND VISIT

Mine	Visit	Min. wind speed (kph)	Min. wind speed (mph)	Max. wind speed (kph)	Max. wind speed (mph)	Mean wind speed (kph)	Mean wind speed (mph)
1	1	2.7	1.7	33.8	21.0	12.9	8.0
	2	.97	.6	24.6	15.3	10.9	6.8
	3	3.9	2.4	43.4	27.0	23.2	14.4
2	1	3.4	4.1	38.3	23.8	20.6	12.8
	2	2.9	1.8	33.6	20.9	14.6	9.1
	3	0.0	0.0	29.0	18.0	8.5	5.3
3	1	4.9	3.0	43.1	26.8	15.8	9.8
	2	0.0	0.0	55.5	34.5	18.5	11.5
	3	1.6	1.0	27.4	17.0	13.8	8.6
4	1	1.9	1.2	32.7	20.3	15.0	9.3
	2	2.3	1.4	32.2	20.0	17.2	10.7
	3	1.9	1.2	32.1	24.8	15.3	9.5

TABLE 8. MINIMUM, MAXIMUM, AND AVERAGE VALUES FOR WIND DIRECTION

Mine	Visit	Minimum angle	Maximum angle	Mean angle
1	1	30.	360.	260.6
	2	0.	355.	289.5
	3	180.	290.	255.3
2	1	0.	355.	278.3
	2	0.	340.	278.6
	3	0.	360.	312.8
3	1	10.	350.	265.4
	2	0.	359.	305.4
	3	75.	295.	196.6
4	1	0.	359.	338.3
	2	70.	345.	249.7
	3	0.	320.	270.7

Angles are given in degrees from due north.

TABLE 9. MINIMUM, MAXIMUM, AND MEAN FOR TEMPERATURE

Mine	Visit	Min. temperature °C	Max. temperature °C	Mean temperature °C
1	1	8.8	32.2	16.9
	2	-29.4	-17.7	-23.3
	3	-21.0	-6.1	-14.8
2	1	8.8	26.7	16.7
	2	-12.2	1.1	-6.7
	3	-28.8	-6.1	-17.0
3	1	7.2	23.3	12.3
	2	-9.4	11.1	1.8
	3	-31.6	-22.2	-28.6
4	1	7.7	27.7	16.1
	2	-13.8	5.5	-5.9
	3	-11.1	-3.3	-13.6

TABLE 10. PRECIPITATION AND SNOW COVER DATA

Mine	Visit	Hours of precipitation	Hours of observation	Snow cover (cm)
1	1	3 (rain)	70	0
	2	23 (snow)	90	10.2-15.2
	3	24 (snow)	73	10.2-35.6
2	1	18 (rain)	73	0
	2	0	73	0
	3	24 (snow)	74	10.2-30.5
3	1	3 (rain)	36	0
	2	2 (rain)	62	0
	3	5 (rain)	75	15.2-35.6
4	1	0	48	0
	2	3 (rain)	72	2.5-10.2
	3	3 (snow)	72	0

The final weather observation concerned atmospheric stability class. Table 11 shows the mean and extreme Pasquill-Gifford stability classes observed at each mine on each visit. The Pasquill-Gifford scale classifies the depth of atmospheric turbulence into six categories. In general, the more stable the atmosphere, the greater the vertical dispersion of a dust plume (Busse and Zimmerman, 1973). The table represents class A, the least stable, as one and class F as six. While the means are similar, the ranges vary considerably. Mine 2 during visit one has a mean stability class of D, the result of a dirunal variation between C and E. Mine 3 during the second visit showed the same mean, but oscillated between B and F. No prominent differences emerge between mines or visits.

MINING ACTIVITIES

Mining activities were recorded during shifts when dust sampling was active. Twelve potential dust producing activities were observed: dragline operation, coal haulage, vehicular traffic on mine roads, vehicular traffic on nearby public roads (usually unpaved), water trucks, scraping, grading, coal loading, coal unloading, blasting and drilling of coal, and drilling of overburden.

The numbers and durations of mining activities varied considerably among mines and across visits. The minimum number of activities observed during the course of a visit was zero; mine 3 was inactive on the first trip. (The inclusion of this data does not lower the estimate of the effect of mining activities. Rather, it helps to predict and correct for the background dust levels due to entrainment of soil by wind in the absence of activities.) The maximum number of activities ever simultaneously conducted was nine. Twelve activities in all were recorded.

Each activity was assigned a measure of duration or intensity. For dragline operation, coal or overburden drilling, scraping or grading, the measure was the number of operating minutes per hour. When operating times were recorded per shift, it was assumed that the operations were uniformly distributed over each hour. Inaccuracies created by this assumption were later reduced when the hourly figures were aggregated over each sampling period, since the periods approximated the shifts in length. Coal haulage and watering were recorded in terms of truck trips. Vehicles on haul roads or other on-mine locations were measured in terms of vehicle-miles driven. Since mileage figures could not be obtained for traffic on public roads, the number of vehicles was recorded. Loading and unloading of coal was logged in terms of tonnage. Blasting was measured by the number of holes shot.

Table 12 shows the total duration or intensity of each mining activity aggregated over all shifts observed on each visit.

All mines but one operated three shifts a day, seven days a week. Mine 1 operated only one shift per day. The dragline was the piece of

TABLE 11. MEAN AND EXTREME STABILITY CLASS

Mine	Visit	Least stable class	Most stable class	Mean class
1	1	2.0	6.0	3.7
	2	1.0	6.0	3.8
	3	3.0	6.0	4.2
2	1	3.0	4.0	4.0
	2	1.0	6.0	3.9
	3	1.0	6.0	3.7
3	1	3.0	6.0	4.2
	2	2.0	6.0	4.0
	3	2.0	6.0	4.3
4	1	1.0	5.0	3.1
	2	2.0	6.0	4.0
	3	2.0	6.0	4.1

TABLE 12. ACTIVITY SUMMARY

Mine	Visit	Dragline operation (min)	Coal haulage (trips)	Vehicles on haul road (km)	Vehicles on public road (vehicles)	Water trucks (trips)	Coal loader (metric tons)	Coal unloader (metric tons)	Blasting (holes)	Coal drill (min)	Overburden drill (min)	Scraper (min)	Grading (min)	Observation length (hrs)
1	1	3846	936	1401	0	0	5260	5260	108	0	0	0	0	80
1	2	2760	271	312	77	0	0	0	140	0	0	0	0	48
1	3	2400	247	296	77	0	0	0	236	0	0	0	0	49
2	1	3854	296	6512	0	6	43790	15120	0	0	0	1200	1440	73
2	2	----	---	----	--	-	----	----	---	---	---	---	---	---
2	3	0	18	384	0	0	0	0	0	0	0	0	0	76
3	1	0	0	0	0	0	0	0	0	0	0	0	0	49
3	2	----	---	----	--	-	----	----	---	---	---	---	---	---
3	3	0	267	267	0	0	17626	0	250	0	0	0	0	85
4	1	0	0	0	0	0	0	0	124	55.2	75.2	3180	67	122
4	2	461	532	1939	461	0	0	0	0	0	0	1372	51	48
4	3	461	544	2403	461	0	0	0	68	0	0	0	6	50

The mines use different sorts of coal transport facilities. In some cases, not all of the loaded coal is unloaded on the mine. Nor are machines specifically designed for loading and unloading always used.

equipment most often in operation, followed by loader and tipple. Blasting was done only during the daytime at all mines.

SPECIAL DUST CONTROL PROCEDURES

Each of the mines employed some dust control procedures. These measures, obtained from observation and interviews with mine operators are briefly described below:

(1) Mine 1: A large watering truck of some 10,000 gallon capacity was observed in operation during preliminary site surveys. The road was watered from the pit where the trucks were loaded to the truck dump point near the mine office. Watering is reportedly done on an as-needed basis. On windy days, watering may be continuous. A cover crop is used on the topsoil stockpiles: oats in the spring, sudan grass in the summer and rye in the fall. This mine was inactive during the first visit and there was snow cover during the second and third. Therefore, watering did not occur at this mine during the actual dust measurements.

(2) Mines 2 and 3: A cover crop is used on topsoil stockpiles. The cover crop, oats and sweet clover, is planted in the spring. Roads are watered during the times of the year when dust is thought to be a problem (chiefly July and August). There are two water trucks. One is used to water the coal haul roads. The other is used on the roads used for topsoil haulage. The trucks work 2 shifts per day. The mine operator is considering using the topsoil watering truck three shifts per day. A cover crop is used on topsoiled areas. The cover crop, oats, can be planted in the spring only. Areas which are topsoiled too late for oats must wait until fall for planting. Areas planted in the fall have no cover until the following spring. This summer (1978) they are going to try sudan grass on the topsoiled areas.

(3) Mine 4: After the spoil is graded, it is ripped. Similarly, after the topsoil is applied it is ripped. This is repeatedly done for several reasons - to reduce compaction, to increase water infiltration or the reservoir capacity of the spoil, to make a better bond between the spoil and the soil, and to reduce wind erosion. The roughness of the spoil and soil causes an eddy effect which reduces the erosive force of the wind. No special dust control procedures are used to control erosion on the topsoil stockpiles. There is quite a bit of volunteer vegetation, however. Also, the vegetation is removed with the

topsoil. This vegetation, particularly the roots, helps hold the soil together.

MISSING DATA

Not all the data prescribed by the experimental design was collected. This resulted from equipment failure and bad weather.

For example, occasionally a dust concentration observation in some size range had to be discarded because the filter froze to the sampler. In this case, the total concentration over all sizes was defined to be missing. Soil moisture data could not be collected when the ground was frozen; hence no moisture data exists for the third round of visits. There was no activity to record during the first trip to mine 3.

On a few occasions, mechanical failures in the high volume samplers prevented data collection. Specifically, this reduced the number of dust concentration observation locations from four to three during parts of two visits. Some weather data were lost when lightning struck a weather station.

Only the frozen ground during the third visit and the lack of activity during the first visit to mine 3 could affect data analysis in any systematic way. The remainder only reduce the number of observations.

SECTION 5

DATA ANALYSIS

INTRODUCTION

This chapter summarizes the results of various statistical analyses of the data collected as part of this study. Specifically, the opening sections of this chapter describe the results of several analyses of variance conducted to determine what, if any, differences in particulates values measured at various locations, mines and seasons, can be held to be statistically significant. Estimates of main and interaction effects together with a complete components of variance analyses are furnished. Results of these analyses have been summarized in Section 1 and are set forth in detail in the following sections, but briefly,

(1) significant differences exist in total particulates at the four mines examined, mine 1 had the largest and mine 2 had the smallest level of particulates,

(2) differences among seasons are obscured to some degree by sample variability. However, there are clear indications that snow cover, in particular, acts to suppress (or is associated with lower) emissions,

(3) initial analysis shows significant interaction effects to exist between mines and visits. If some activity related adjustments are made, the interaction effects are lowered substantially and a significant seasonal effect emerges and finally,

(4) significant differences exist among various sampler locations for a given mine visit. This is later shown to reflect ambient vs. downwind differences.

The next sections of this chapter use the constructive method of Box and Cox (Journal of the Royal Statistical Society, 1964, see bibliography) to show that a logarithmic (log) transformation of the data is appropriate in that the assumptions which underlie the statistical techniques are more nearly met if the data are transformed prior to analysis. Specifically, the use of the log transformation makes the deviations from predicted values approximately normal (normality) and with constant variance (homoscedastic). The power law transformation also acts to remove possible outliers in the data base. Replicate analysis with and without candidate outliers shows the above conclusions are not sensitive to this consideration.

The next sections explore and detail further the finding of differences among samplers. It is shown that these differences arise largely between the ambient sampler and those downwind of the mining operation - though the difference is statistical rather than one-to-one. That is, measured particulate values from downwind samplers were sometimes lower than corresponding upwind (ambient) samplers. This implies that the level of dust not due to mining activities was at times greater upwind of the activities than downwind. Despite this, the mean particulate values corresponding to the downwind samplers is some 30+% higher than background values. The 95% confidence interval on this increment ranges from about 8% to 64% higher than upwind.

An analysis of the correlates of ambient particulates is presented next. Regression analysis shows that ambient particulates are positively correlated with wind speed (to the 0.34 power) and negatively correlated with snow cover, though the sample size is not sufficiently large to achieve statistical significance.

The concluding sections of this chapter explore the relationship between particulates and activity variables at the mining operations visited. Though obscured by problems endemic to observed rather than designed experiments, a significant relationship is found. Key variables which emerge as statistically significant predictors of TSP include wind speed, vehicle counts on nearby public roads, on-mine vehicles (though with an incorrect sign, an anamoly that is explained in the discussion of multicollinearity on pages 72 and 76), coal haulage and dragline operation. The overall multiple correlation coefficient was 0.58 - highly significant if not spectacular. A parallel site-specific analysis shows that mine to mine differences are at least as important if not more so than the quantitative activity levels measured. Consideration of site-specific effects (dummy variables associated with each mine and each visit) raised the multiple correlation coefficient to about 0.65.

In all, the analyses demonstrate significant trends, differences and relationships which are generally in accord with physical theory, intuition and the findings of other investigators. These effects are submerged in considerable variability, however, reflecting the substantial contribution of experimental variability and other (unmeasured) exogenous factors.

The results are useful, nonetheless, as illustrative of the relationships likely to be found in practical situations where many of the variables are not controllable. The statistical analyses may also be of use and interest to future investigators as a paradigm for exploration. (In a more technical sense, of particular interest are the methods used to treat missing observations, various schemes to evaluate additivity, normality and homoscedasticity and the exposition of various adjustment schemes to eliminate or minimize interaction effects.) The next paragraphs are ventured to facilitate understanding of the presentation of the statistical analysis.

The analysis described in the following sections is presented in a sequence that parallels the sequence of exploration. Thus, for example, an overall analysis of variance is first conducted to detect what might be termed 'gross structure' in the data, i.e., are there differences among mines, visits, etc. For this purpose other variables (such as mine activity levels) are omitted and submerged into the 'noise' of measurements. Later, in an exploration of 'fine structure', these variables are brought into the analysis to help explain or rationalize findings of the preliminary analysis. This method of exposition should be of value to future investigators seeking to develop a strategy for data analysis.

Finally, statistical computations and conventions which are commonly employed, for example, the layout of an analysis of variance table, are omitted in the interests of brevity and continuity. Useful textbooks or articles are included as references should the reader wish a more detailed presentation.

DATA AND ASSUMPTIONS

This section reports the results of preliminary statistical analysis of the data, in particular, an analysis of variance (ANOVA) on total particulates. These data consist of measurements of particulates in various size ranges at four different sampler locations for several operating shifts in each of three visits (late summer, fall, and early winter) to each of four mines. Complete data is shown in the appendix.

The data are first aggregated over all size ranges to total suspended particulates (TSP). Table 13 shows these computed quantities for the first seven sampling intervals for which data in all size ranges was available. As explained earlier, operational limitations resulted in some missing data for certain shifts, locations and visits. Following generally accepted practice (see for example the Bennett and Franklin reference in the bibliography), missing values were estimated by appropriate row means to simplify subsequent analysis. Thus, for example, only five particulate data points were available in the fourth location in the first visit to the first mine. In Table 13, these quantities are estimated as the mean (114) of the preceeding five observations. These estimated values and all other missing values which were estimated are circled in the data matrix. As a second example, operational difficulties precluded data collection from location four in the second visit to the first mine. For purposes of the analysis of variance, the seven missing values are estimated as the mean across all sampler locations and sampling intervals for this visit to this mine. (Corresponding adjustments are made to degrees of freedom in the ANOVA to account for the use of estimated quantities for missing observations.)

TABLE 13. RAW DATA AND ESTIMATES OF MISSING DATA FOR FIRST SEVEN SAMPLING INTERVALS

Mine	Visit	Sampler Location	Total particulates ($\mu g/m^3$)						
1	1	1	155	497	138	95	146	139	105
		2	79	164	120	122	94	105	109
		3	134	123	80	70	166	109	114
		4	137	106	83	109	109	109	109
	2	1	304	53	72	63	210	251	300
		2	781	99	98	85	335	133	288
		3	564	83	189	147	143	174	282
		4	222	222	222	222	222	222	222
	3	1	411	778	277	69	53	117	284
		2	559	1600	1514	399	266	80	33
		3	94	531	649	156	150	75	60
		4	863	330	51	96	139	120	58
2	1	1	126	134	156	89	58	98	110
		2	125	125	125	125	125	125	125
		3	178	173	221	70	89	95	110
		4	204	248	109	100	143	161	161
	2	1	35	242	152	94	185	312	149
		2	87	244	294	178	184	606	73
		4	111	75	93	93	93	93	93
		5	118	116	209	63	92	138	164
	3	1	70	15	31	71	55	53	21
		2	57	63	61	59	27	32	49
		3	43	81	33	38	95	39	99
		4	50	49	110	63	103	37	66

NOTES: The three seasons correspond to the three visits. Their data are given on page 2.

TABLE 13. (continued)

Mine	Visit	Sampler Location	Total particulates ($\mu g/m^3$)						
3	1	1	77	87	99	146	149	243	182
		2	130	95	94	255	88	77	97
		3	108	122	140	111	140	143	230
		4	71	142	101	129	129	114	114
	2	6	171	211	103	103	121	101	133
		7	101	273	178	119	215	115	88
		8	1337	180	772	163	396	221	192
		9	252	252	252	252	252	252	252
	3	5	71	40	51	258	25	65	65
		6	32	70	39	17	17	47	33
		7	50	288	13	204	59	29	68
		8	39	44	28	59	110	20	36
4	1	1	222	92	97	214	145	154	154
		2	78	77	97	105	98	87	96
		3	111	130	133	230	123	263	153
		4	71	142	101	129	119	112	112
	2	1	387	137	82	104	64	85	97
		2	116	108	45	94	314	262	182
		3	80	150	69	82	181	111	169
		4	308	316	218	62	116	204	204
	3	1	58	71	119	18	92	70	96
		2	78	77	38	65	96	95	144
		3	82	82	97	164	105	218	121
		4	136	129	83	122	163	127	185

NOTES: Circled figures denote missing observations and are estimates.
Data are for first seven shifts of data.
When less than 3 samplers are used, values for the 4th are estimated.

TYPING GUIDE SHEET

ANOVA: BEGINNINGS OF A SEARCH FOR STRUCTURE

For purposes of the initial exploratory analysis, data taken during different sampling intervals are considered replicate determinations. In fact, such data reflect the error of sampling replications together with whatever systematic effects are introduced by differences in operating conditions (e.g., truck traffic on haul roads, dragline and loader operations, etc.) over the intervals in which data was collected. As a consequence, this simplification may overstate the variability over replicates and 'bury' real trends or differences in the 'noise' of replicates. However, any differences that are statistically significant given this assumption will indeed be significant given a smaller mean square error that might result when systematic effects are removed from the error residual. Subsequent analyses will attempt to remove systematic effects from the error estimates and unearth the "fine structure" in the data.

Given the assumption that data from different sampling intervals at each mine visit are replicates, the experimental design can be characterized in technical terms as a mixed 'crossed' and 'nested' design. (Such a characterization is important because it defines the requisite computational schemes and tests of significance.) Sampler locations, for example, are nested within mines and season. This is because the actual placement of samplers varied from trip to trip depending upon wind conditions, mine activity, and other factors. The sampler location numbers 1 through 4 differentiate between locations for that visit at that mine: they do not imply, for example, that location 1 at any mine visit will be any more closely related to the #1 sampler at any other visit than to the #2 sampler, hence locations are nested. Seasons (visits) and mines, on the other hand, form a crossed classification. The conventional mathematical model corresponding to this design and assumptions is then:

$$y_{ijk\alpha} = \mu + \xi_i + \eta_j + \beta_{ij} + \lambda_{k(ij)} + \epsilon_{\alpha(ijk)} \qquad (2)$$

where μ = overall mean

ξ_i $(i=1,p)$ and η_j $(j=1,q)$ = main effects of mines and seasons respectively (note μ defined so that $\Sigma\xi_i = \Sigma\eta_j = \Sigma\lambda_{k(ij)} = 0$)

and

β_{ij} = the interaction effect of mines and seasons,

$\lambda_{k(ij)}$ = the random effects between the sampler locations obtained from the 'cell' ij and,

$\epsilon_{\alpha(ijk)}$ = random error term.

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

In words the above equation assumes that the observed level of particulates over each sampling interval at each visit to each mine ($y_{ijk\alpha}$) can be represented as an additive linear combination of an overall constant (μ) plus a contribution due to each mine (ξ_i), each visit (a surrogate for seasonality η_j), an interaction term (β_{ij}) to capture the possibility, for example, that the seasonal effects might differ among mines, and a sampler effect ($\lambda_{k(ij)}$) to reflect differences in sampler placement. Finally, an error term, $\epsilon_{\alpha(ijk)}$ is included to reflect measurement and other sources of variability not included in the model (one example would be variations in activity levels among mines). Subsequent computations will estimate the magnitude of each of these effects and compare these estimates to the size of the error term - in this way the statistical significance of the effects can be adjudged.

Bennett and Franklin (op. cit.) among others details the requisite equations and sequence of computations for the analysis of variance. For this purpose it is necessary to partition the overall variability, measured as the sum of squares about the overall mean denoted by S, into its components. Accordingly, the breakdown of the sum of squares which provides variance estimates corresponding to these terms is,

$$S = S_i + S_j + S_{ij} + S_{k(ij)} + S_{\alpha(ijk)},$$

an equation which parallels eq(2) in concept and notation. The analysis of variance has been computed under two sets of assumptions:

(A) mines and locations are viewed as being a random (or at least representative) sample, while seasons are regarded as fixed -- i.e., estimates are for these three seasons only.

(B) as above, except that seasons are also viewed as random effects.

Assumption (A) appears more nearly correct and will be emphasized in the following discussion of results. The formal analysis of variance together with the average values of the variance estimates is given in Tables 14 and 15 for each of the assumptions. As can be seen, these differ only with respect to the expected value of the mean square (and hence in the appropriate F statistics for significance testing). The algorithm for computation of expected value of the mean square can be found in Bennett & Franklin (op. cit. pp. 414 et seq.) and is not repeated here.

For the reader interested in following or checking the details of computation, two intermediate tables are presented: Tables 16 and 17.

Table 16 contains appropriate sums and subtotals of data elements necessary for analysis of variance computations. Table 17 details appropriate formulae and computational results for necessary sums of

EPA-287 (Cin.)
(4-76)

TABLE 14. ANALYSIS OF VARIANCE TABLEAU FOR EXPLORATORY ANALYSIS
ANOVA 1: MINES AND LOCATIONS RANDOM, SEASONS FIXED

	Sum of squares	Degrees of freedom	Average value of **mean square**
Between mines	S_i	p-1	$^{2}+n\sigma_{\lambda}^{2}+qrn\sigma_{\xi}^{2}$
Between seasons	S_j	q-1	$\sigma^2+n\sigma_{\lambda}^{2}+rn\sigma_{\beta}^{2}+prn\sigma_{\eta}^{2}$
Mines X seasons interaction	S_{ij}	(p-1)(q-1)	$\sigma^2+n\sigma_{\lambda}^{2}+rn\sigma_{\beta}^{2}$
Between Location (within mines & seasons)	$S_{k(ij)}$	pq(r-1)	$\sigma^2+n\sigma\lambda^2$
Between replicates (within location, mines and season)	$S_{\alpha(ijk)}$	pqr(n-1)	σ^2
Total	S	pqrn-1	

TABLE 15. ANALYSIS OF VARIANCE TABLEAU FOR EXPLORATORY ANALYSIS
ANOVA 2: MINES, SEASONS AND LOCATIONS RANDOM

Source of estimate	Sum of squares	Degrees of freedom	Average value of mean square
Between mines	S_i	p-1	$\sigma^2+n\sigma_\lambda{}^2+rn\sigma_\beta{}^2+qrn\sigma_\xi{}^2$
Between seasons	S_j	q-1	$\sigma^2+n\sigma_\lambda{}^2+rn\sigma_\beta{}^2+prn\sigma_\eta{}^2$
Mines X seasons interaction	S_{ij}	(p-1)(q-1)	$\sigma^2+n\sigma_\lambda{}^2+rn\sigma_\beta{}^2$
Between locations (within mines & seasons)	$S_{k(ij)}$	pq(r-1)	$\sigma^2+n\sigma\lambda^2$
Between replicates (within location, mines and season)	$S_{\alpha(ijk)}$	pqr(n-1)	σ^2
Total	S	pqrn-1	

TABLE 16. ANCILLARY TABLES - SUMS OF RAW DATA

A: Sums over replicates T_{ijk}

Mine	1			1			1			1		
Season	1	2	3	1	2	3	1	2	3	1	2	3
Sampler*												
1	1275	1253	1989	771	1169	316	983	943	575	1078	956	524
2	793	1819	4451	875	1666	348	836	1089	255	638	1121	593
3	796	1582	1715	936	651	428	994	3261	711	1143	842	869
4	762	1554	1657	1126	900	478	800	1764	336	786	1428	945

* Refers to 1st four samplers for that mine and visit in numerical order.

B: Sums over locations $T_{ij.}$

Mine	1	2	3	4
Season 1	3626	3708	3613	3645
Season 2	6208	4386	7057	4347
Season 3	9812	1570	1877	2931

C: Typical element $T_{.j.}$

Season	1	2	3
Subtotal	14592	21998	16190

D: Typical element $T_{i..}$

Mine	1	2	3	4
Subtotal	19646	9664	12547	10923

TABLE 17. ANALYSIS OF VARIANCE COMPUTATIONS

Preliminary values	Sums of squares
$C_{ijk\alpha} = \sum_i \sum_j \sum_k \sum_\alpha y^2_{ijk\alpha} = 18{,}273{,}760$	$S_i = C_i - C = 710{,}305$
$C_i = 1/84 \sum_i T^2_{i..} = 8{,}895{,}799$	$S_j = C_j - C = 271{,}152$
$C_j = 1/112 \sum_j T^2_{.j.} = 8{,}456{,}646$	$S_{ij} = C_{ij} - C_j - C_i + C = 1{,}105{,}063$
$C_{ij} = 1/28 \sum_i \sum_j T^2_{ij.} = 10{,}272{,}014$	$S_{\alpha(ijk)} = C_{ijk\alpha} - C_{ijk} = 6{,}515{,}193$
$C_{ijk} = 1/7 \sum_i \sum_j \sum_k T^2_{ijk} = 11{,}759{,}577$	$S = C_{ijk\alpha} - C = 10{,}089{,}266$
$C = T^2/N = 8{,}185{,}494$	$S_{k(ij)} = S - S_{\alpha(ijk)} - S_{ij} - S_j - S_i = 1{,}486{,}563$

squares computations. Finally, Tables 18 and 19 show the analysis of variance tableau for assumptions A and B respectively.

Reference to Table 18 (untransformed ANOVA) enables the following tentative conclusions to be drawn:

(1) There is significantly greater variability between sampler locations (within mines and seasons) than between replicates (within location, mine, and season). The computed test statistic or F ratio is 1.66, a quantity which exceeds the critical value necessary to demonstrate significance at the 95% (.05) level given the sample sizes. The estimate of the standard deviation within replicates (as shown in Table 20) is 162.1. The additional variability between locations, σ_λ, is 49.9.

(2) There are significant interaction effects between mine and season. The computed F ratio, 4.21, exceeds the threshold level at the 95% level. Estimated values of these interaction effects will be presented later in this section. However, (ref. Table 20), the components of variance estimates σ_β as 70.8.

(3) Based upon the assumption that data from separate sampling intervals are replicate values, there is not sufficient evidence to assert that seasonal differences are significant (subsequent analyses will qualify or modify this conclusion). The computed F ratio falls beneath the critical level and, indeed, the components of variance analysis resulted in a computed value for σ_η that was negative and set equal to zero.

(4) There are significant differences among mines. The computed F statistic, 5.41, exceeds the critical value required to assert significance. The components of variance analysis shows $\sigma_\xi = 47.9$, of comparable magnitude to the other significant effects and about 30% of the standard error among replicates.

NUMERICAL ESTIMATES OF MAIN EFFECTS AND INTERACTION TERMS

Table 22 shows appropriate computational formulae and numerical estimates for the various terms in the model,

$$E\left[y_{ij}\right] = \mu + \xi_i + \eta_j + \beta_{ij}. \qquad (3)$$

The overall mean value for particulates, μ, is estimated as 157.1 ($\mu g/m^3$). The significant main effects due to mines, ξ_i, are shown next. Mine 1 had the largest estimated particulates (mean value 233.9

TABLE 18. ANALYSIS OF VARIANCE TABLEAU: MINES. LOCATIONS RANDOM AND SEASONS FIXED

Source of estimate	Sum of squares	Degrees of freedom	Mean square	Average value of mean square	Computed F statistic
Between mines	710,305	3	236,768	$\sigma^2+7\sigma_\lambda^2+84\sigma_\xi^2$	5.41*
Between seasons	271,152	2	135,576	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2+112\sigma_\eta^2$	.74
Interaction mines X seasons	1,105,063	6	184,177	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2$	4.21*
Between locations (within mines & seasons)	1,486,563	34[1]	43,722	$\sigma^2+7\sigma_\lambda^2$	1.66*
Between replicates (within location, mines & seasons)	6,515,193	248	26,271	σ^2	
Total	10,089,266	293[2]			

[1] $\Sigma pq(v_i-1)$ to reflect missing observations

[2] Adjusted to reflect 42 missing observations

* Denotes significant difference at 0.05 level.

TABLE 19. ANALYSIS OF VARIANCE TABLEAU: MINES. SEASONS AND LOCATIONS RANDOM

Source of estimate	Sum of squares	Degrees of freedom	Mean square	Average value of mean square	Computed F statistic
Between mines	710,305	3	236,768	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2+84\sigma_\xi^2$	1.29
Between seasons	271,152	2	135,576	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2+112\sigma_\eta^2$	.74
Interaction mines X seasons	1,105,063	6	184,177	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2$	4.21*
Between locations (within mines & seasons)	1,486,563	34 [1]	43,722	$\sigma^2+7\sigma_\lambda^2$	1.66*
Between replicates (within location, mines & seasons)	6,515,193	248	26,271	σ^2	
Total	10,089,266	293 [2]			

[1] $\Sigma pq(v_i-1)$ to reflect missing observations

[2] Adjusted to reflect 42 missing observations

* Denotes significant difference at 0.05 level.

TABLE 20. COMPONENTS OF VARIANCE ESTIMATES:
MINES AND LOCATIONS RANDOM, SEASONS FIXED

Term	Estimate	Numerical value
σ	$\left[s^2_{\alpha\,(ijk)}\right]^{1/2}$	162.1
σ_λ	$\left[\dfrac{s^2_{k(ij)}-s^2_{\alpha(ijk)}}{n}\right]^{1/2}$	49.9
σ_β	$\left[\dfrac{s^2_{ij}-s^2_{k(ij)}}{nr}\right]^{1/2}$	70.8
σ_η	$\left[\dfrac{s^2_{j}-s^2_{ij}}{prn}\right]^{1/2}$	0[1]
σ_ξ	$\left[\dfrac{s^2_{i}-s^2_{k(ij)}}{qrn}\right]^{1/2}$	47.9

---

[1] Computed quantity was negative so set equal to zero.

TABLE 21. COMPONENTS OF VARIANCE ESTIMATES: MINES, SEASONS AND LOCATIONS RANDOM

Term	Estimate	Numerical value
σ	$\left[s^2_{\alpha(ijk)}\right]^{1/2}$	162.1
σ_λ	$\left[\frac{s^2_{k(ij)}-s^2_{\alpha(ijk)}}{n}\right]^{1/2}$	49.9
σ_β	$\left[\frac{s^2_{ij}-s^2_{k(ij)}}{nr}\right]^{1/2}$	70.8
σ_η	$\left[\frac{s^2_{j}-s^2_{ij}}{prn}\right]^{1/2}$	0[1]
σ_ξ	$\left[\frac{s^2_{i}-s^2_{ij}}{qrn}\right]^{1/2}$	25.0

---

[1] Computed quantity was negative so set equal to zero.

TABLE 22. NUMERICAL ESTIMATES OF MAIN EFFECTS AND INTERACTION TERMS

Effect	Estimate	Numerical value ($\mu g/m^3$)
overall mean	$\bar{y}$	$\mu = 157.1$
main effect Mines ξ_i *	$\bar{y}_{i..}-\bar{y}$	$\xi_1 = 233.9-\bar{y} = 76.8$ $\xi_2 = 115-\bar{y} = -42.1$ $\xi_3 = 149.4-\bar{y} = -7.7$ $\xi_4 = 130-\bar{y} = -27.0$
main effect Seasons η_j	$\bar{y}_{.j.}-\bar{y}$	$\eta_1 = 130.3-\bar{y} = -26.8$ $\eta_2 = 196.4-\bar{y} = 39.3$ $\eta_3 = 144.6-\bar{y} = -12.5$
interactions Mines X Seasons β_{ij} *	$\bar{y}_{ij.}-\bar{y}_{i..}-\bar{y}_{.j.}+\bar{y}$	$\beta_{11} = -77.6$ $\beta_{12} = -51.5$ $\beta_{13} = 129.0$ $\beta_{21} = 44.2$ $\beta_{22} = 2.3$ $\beta_{23} = -46.4$ $\beta_{31} = 6.4$ $\beta_{32} = 63.3$ $\beta_{33} = -69.9$ $\beta_{41} = 27.0$ $\beta_{42} = -14.1$ $\beta_{43} = -12.8$

*These differences are statistically significant.

$\mu g/m^3$) hence a value +76.8 $\mu g/m^3$ higher than the overall mean while mine 2 had the smallest (11.50 $\mu g/m^3$). As will be discussed later, these differences can partially be explained by differences in activity patterns.

As highlighted in point 3 above, seasonal effects cannot be held to be significant. This result is somewhat surprising as, at least in winter, when much of the ground is snow-covered, particulates might be expected to be lower. All four mines had snow cover in the early winter visit. The main effect for this season, η_3, is indeed negative 12.5 $\mu g/m^3$ less than the overall mean, but in view of the overall variability this is a small effect. More puzzling is the size and magnitude of the main effect for season 1, -26.8. It is often assumed that particulates are more of a problem in the summer, an observation of variance with this data. The following analysis potentially resolves this contradiction.

Interaction effects for each mine and season, denoted by β_{ij} (i = 1, 4: j = 1, 3) are significantly different from zero. Some of the largest interaction effects are associated with mine 1, with lower than expected (on the basis of main effects alone) particulates in seasons 1 and 2 and higher than expected particulates in season 3. Mines 2 and 3 each had substantial negative interaction terms for season 3 (early winter).

The presence of significant interaction effects serves both to complicate the model and make interpretation of results more difficult. The section following, entitled "The Choice of a Transformation" examines the use of power law transformations to achieve model additivity (absence of interaction) as well as other statistical properties. The balance of this section explores a somewhat more speculative approach to the examination of interaction effects.

In the context of this experimental design, interaction effects are measuring the (possibly unique) circumstances at each visit at each mine. Literally these effects are defined by the difference in response between what can be accounted for by whatever main effects exist and the observed particulates for that visit. Thus, for example, in the absence of interaction, the expected mean particulates for visit 3 to mine 1 is the overall mean, 157.1 $\mu g/m^3$, plus the main effect due to mine 2, 76.8 $\mu g/m^3$ (see Table 22) plus the main effect due to season 3, -12.5 $\mu g/m^3$ (see Table 22) or 221.4 $\mu g/m^3$. The observed mean value (see Table 16) is 9812/28 = 350.4 $\mu g/m^3$. The interaction term, β_{13}, is then 350.4 - 221.4 = 129.0 $\mu g/m^3$ as shown in Table 22. β_{13} is, in fact, the largest of the computed interactions. It is tempting to see if any assignable cause can be identified to "explain" this interaction. If one can be found and a more reasonable estimate of the response substituted for the observed value (350.4 $\mu g/m^3$), then recomputation of the main effects may lead to additional insights. Though the search for an explanation may have been initiated by the presence of a large interaction, the burden of proof for adjustment of cell values must be based upon physical rather than statistical grounds.

A detailed examination of the data recorded in visit 3 to mine 1 suggests one anamoly - dragline activity during this visit was an order of magnitude greater than at the other mines during this visit. It is reasonable to expect (and later shown to be true) that dragline activity is associated with increased emissions and hence increased particulates. Thus a possible explanation for this observed interaction is the higher than normal activity. If this is true, then for purposes of the ANOVA (evaluation of main and interaction effects) it is appropriate to make some adjustment to the observed response and recompute the main effects and interaction terms.

The most common procedure for such cell adjustment (see for example a recent article by Daniel, Technometrics Vol. 20, #4, November, 1978) is to regard the anamolous response as missing data. An estimate of the value to assign to the cell is then obtained so as to minimize the sum of squares of interaction terms. Table 23 following shows the mean values, and row and column means for all visits to all mines. An unknown value, y_{13}, is assigned to the response to be estimated.

Following the usual partitioning into the components of the sum of squares for the ANOVA, we obtain:

(a) Correction term: $C = 1/12\ (1534.5 + y_{13})^2$ (4)

(b) Between Mines:

$$1/3\ [(351.2 + y_{13})^2 + 345.1^2 + 448.^2 + 390.2^2] - C \qquad (5)$$

(c) Between Seasons:

$$1/4\ [521.1^2 + 785.6^2 + (227.8 + y_{13})^2] - C \qquad (6)$$

(d) Between Observations:

$$[129.5^2 + 221.7^2 + y_{13}^2 + \ldots + 104.7^2] - C \qquad (7)$$

The interaction (or residual) component is computed as (7) - (6) - (5), and, neglecting purely numerical terms which will disappear on differentiation, the sum of squares, S, becomes:

$$\begin{aligned} S = y_{13}^2 + \ldots &+ 1/12\ (y_{13}^2 + 30{,}690\ y_{13} + \ldots) \qquad (8) \\ &- 1/3\ (y_{13}^2 + 70{,}240\ y_{13} + \ldots) \\ &- 1/4\ (y_{13}^2 + 45{,}560\ y_{13} + \ldots) \end{aligned}$$

Obtaining the partial derivative of (8) with respect to y_{13}, setting this equal to zero and solving for $\hat{y}_{13}$ yields the value 92.2. In other words 92.2 is the adjusted cell mean for particulates in visit 3 to mine 1: an estimate of the particulates that would have been obtained in the absence of the unique conditions of this visit.

TABLE 23. MEAN VALUES FOR "WHAT IF" ANALYSIS

		Mine				Total $T_{.j}$	Mean $y_{.j}$
		1	2	3	4		
	1	129.5	132.4	129.0	130.2	521.1	130.3
Season	2	221.7	156.6	252.0	155.3	785.6	196.4
	3	y_{13}	56.1	67.0	104.7	$227.8+y_{13}$	$57.0+y_{13}/4$
Total,	$T_{i}\cdot$	$351.2+y_{13}$	345.1	448.0	390.2	$1534.5+y_{13}$	
Mean,	$\bar{y}_{i}\cdot$	$117.1+y_{13}/3$	115.0	149.3	130.1	$127.9+y_{13}/12$	

NOTE: The seasons correspond to the three visits. Their dates appear on page 2.

TYPING GUIDE SHEET

This estimate, $\hat{y}_{13}$, in turn can be used (in conjunction with the other values shown in Table 23) for recomputation of main and interaction effects under this "what if" hypothesis. These computations are summarized in Table 24. Results of this speculation are interesting. The seasonal effects are now more pronounced and, in particular, the seasonal effect corresponding to winter conditions, -55.6, is negative and of appreciable magnitude. The magnitude of the contraintuitive seasonal effect for the summer season, $-26.8\mu g/m^3$, has been reduced to 80% to $-5.3\mu g/m^3$, a happy consequence. Note also that the other interaction effects β_{ij} are appreciably smaller than in the original analysis shown in Table 22 - the root mean square interaction term dropped by nearly 60% from 59.9 to 24.8. Such results are certainly plausible if not definitive.

In the following section we explore yet other approaches for sharpening the results of the ANOVA.

THE CHOICE OF A TRANSFORMATION

There are several assumptions which underlie the ANOVA procedure. Of particular relevance in this context are the assumptions of homogeneity of variance and normality of residuals.

If the variance of the random components in an analysis differs from cell to cell, the ANOVA procedure leads to a loss in efficiency in the estimation of effects and (possibly) a distortion of the significance level of comparisons. This is because all observations are weighted equally in deriving the estimates of effects, a procedure which is inappropriate if observations have different errors. The significance level of the results may be distorted because a common variance estimate is used in examining all comparisons rather than a series of different variance estimates.

If the residuals do not satisfy the distribution assumptions (i.e. normally distributed) upon which the test procedures are based, then the statistical significance of the results may be misstated. In practice, however, even substantial deviations from normality appear not to affect the results greatly -- the ANOVA procedure is said to be robust.

An examination of the residuals from the predicted values of TSP at each mine, season, and location indicates that:

(1) the residuals do not appear to be normally distributed, but rather come from some 'long tail' distribution (e.g. gamma, Weibull, log-normal, etc.)

(2) the residual variance is not constant from cell to cell and appears to be an increasing function of cell mean and

(3) there may be some outliers present in the data.

EPA-287 (Cin.)
(4-76)

TABLE 24. CONSEQUENCES OF DELETING DATA FROM MINE 1 SEASON 3

UNTRANSFORMED DATA - ALL UNITS IN $\mu g/m^3$

(A) Main effects

	Mine				$y_{\cdot j}$	η_j
	1	2	3	4		
1	129.5	132.4	129.0	130.2	130.3	- 5.3
Season 2	221.7	156.6	252.0	155.3	196.4	60.8
3	92.2	56.1	67.0	104.7	80.0	-55.6
$\bar{y}_{i\cdot}$	147.8	115.0	149.3	130.1	μ =135.6	
ξ_i	12.2	- 20.6	13.7	- 5.5		

*Estimated value

(B) Interaction and/or error terms (β_{ij})

	Mine			
	1	2	3	4
1	- 13.1	22.7	- 15.0	5.4
Season 2	13.1	- 19.2	41.9	- 35.6
3	0	- 3.3	- 26.7	30.2

NOTE: The seasons correspond to the three visits. Their dates appear on page 2.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

The first two points above suggest some transformation be applied to the data in an attempt to remove the heteroscedasticity and apparent non-normality. In a seminal paper in 1964, referenced earlier, Box and Cox developed a constructive algorithm for choosing a transformation. The parametric family of tranformations considered by Box and Cox are of the form:

$$y^{(\theta)} = \begin{cases} \dfrac{y^{\theta} - 1}{\theta} & \theta \neq 0 \\ \ln y & \theta = 0 \end{cases} \qquad (9)$$

The above transformation holds for $y > 0$. For a value of $\theta = 0$, (9) is a logarithmic transformation, for $\theta = -1$, (9) is a reciprocal transformation, while for $\theta = 1$, (9) leaves the data unaltered.

REVIEW OF RELEVANT THEORY

A brief sketch of the main ideas in the Box and Cox paper follows:

(1) The data $y_1 \ldots y_n$ are assumed to be generated by a linear model of the form $E[y^{(\theta)}] = aw$, where a is a known matrix, θ is as defined above and w a vector of unknown parameters associated with the transformed observations.

(2) For some unknown θ, the transformed observations $y_i^{(\theta)}$ are assumed to satisfy full normal theory assumptions independently normally distributed with constant variance σ^2 and expectation $E[y^{(\theta)}] = aw$. The probability density function (pdf) for the untransformed observations and the likelihood in relation to the original observations is obtained by multiplying the normal density by the Jacobian of the transformation as

$$\frac{1}{(2\pi)^{n/2}\sigma^n} \exp \left\{ - \frac{(y^{(\theta)} - aw)'\,(y^{(\theta)} - aw)}{2\;{}^2} \right\} J(\theta;y),$$

$$\text{where } J(\theta;y) = \prod_{i=i}^{n} \left| \frac{dy_i^{(\theta)}}{dy_i} \right| \qquad (10)$$

(3) The above likelihood (10) is, except for a constant factor, the likelihood for a standard least squares problem. Hence the maximum likelihood estimates for the dependent variable $y^{(\theta)}$ and the estimate of σ^2, denoted for a fixed θ by $\hat{\sigma}^2(\theta)$ is

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

EPA-287 (Cin.)
(4-76)

$$\hat{\sigma}^2(\theta) = y^{(\theta)\prime}\ (I - a(a'a)^{-1}a')y^{(\theta)}/n = S(\theta)/n$$

More simply, if the normalized transformation

$$z^{(\theta)} = y^{(\theta)}/J^{1/n} \text{ where } J = J(\theta;y)$$

is used then the maximized log likelihood is given by

$$L_{max}^{(\theta)} = -1/2n\ \ln\left[\hat{\sigma}^2(\theta;z)\right]$$

and $$\hat{\sigma}^2(\theta:z) = \frac{S(\theta:z)}{n}$$

where $S(\theta:z)$ is the residual sum of squares of $z^{(\theta)}$.

For the power transformation

$$z^{(\theta)} = \frac{y^{\theta} - 1}{\theta \dot{y}^{\theta-1}}$$

where $\dot{y}$ is the geometric mean of the data

(4) The best value of θ to choose under the assumption of an additive, homoscedastic and normal model in the transformed observations can be found by minimizing the residual sum of squares (in an additive model, estimated by the pooled residual and interaction sum of squares, that is $S_{ij} + S_{\alpha(ijk)}$in the notation of the foregoing) of the normalized z values as a function of θ. The maximized log-likelihood under the assumptions of additivity, homoscedasticity and normality, denoted by

$L_{max}\ (\theta|A,H,N)$ is given by,

$$L_{max}\ (\theta|A,H,N) = -1/2\ n\ \ln\ \left[\frac{S(\theta:z)}{n}\right] \qquad (11)$$

(5) The best value of θ to choose under the less restrictive assumptions of homoscedasticity and normality can be found by the procedure above where the criterion function is the residual sum of squares. The maximized log-likelihood under the assumptions of homoscedasticity and normality, denoted by

$L_{max}\ (\theta|H,N)$ is given by,

$$L_{max} \; (\theta | H,N) \; + \; -1/2 \; n \; \ln \left[\frac{S_v(\theta : z)}{n} \right] \qquad (12)$$

where $S_{\alpha} (\theta : Z) = S_{\alpha(ijk)}$ in the ANOVA notation

APPLICATION TO PARTICULATES DATA

Table 25 and Figure 2 show results of numerical optimization of the log-likelihoods $L_{max} (\theta | A, H, N)$ and $L_{max} (\theta | H, N)$ respectively. On the basis of either criterion, the optimal value of θ, $\hat{\theta}$ is about -0.1 -- that is, approximately equal to the value $\theta = 0.0$ which corresponds to a logarithmic transformation of the data. Indeed, an approximate 100 $(1 - \alpha)$ percent confidence region for θ can be found from

$$L_{max}(\hat{\theta}) - L_{max}(\theta) \leq 1/2 \, X^2_{v_\theta} \; (\alpha) \qquad (13)$$

where v_θ is the number of independent components (in this case one) in θ. A 99.5% confidence interval, therefore, includes all θ values with log-likelihood within (7.88/2) of the minimum value. Thus, the value 0 is included in this confidence interval for the additive, homoscedastic normal model.

The logarithmic transformation is intuitively plausible and has been shown above to be an appropriate model for particulates data. It will be employed henceforth in the analysis procedure.

Table 26 details appropriate formulae and computational results for necessary sums of squares computations with the logarithmically transformed data. It corresponds to Table 17 for the untransformed data. Finally, Table 27 shows the analysis of variance tableau on the assumption of fixed seasonal effects.

Interestingly, the conclusions that emerge from this analysis are identical with those reported for the untransformed data, viz;

(1) a significant main effect for mines,

(2) no proven significant effect for seasons,

(3) a signficant interaction effect between mines and seasons. Unfortunately, the "best" transformation failed to achieve additivity in this instance and finally,

(4) significant differences among locations within mines and seasons.

TABLE 25. NUMERICAL SEARCH TO SELECT OPTIMAL TRANSFORMATION

Transformation name	θ	$S(\theta; z)$	$L_{max}(\theta \mid A,H,N)$ 1/	$S_{\nu}(\theta; z)$	$L_{max}(\theta \mid H,N)$ 2/
Square	2.0	2,365,278.25	-1,488.36	2,156,767.00	-1,472.86
Untransformed	1.0	76,191.62	- 911.21	65,147.25	- 884.91
Square root	0.5	26,000.62	- 730.59	21,175.00	- 696.10
	0.4	22,510.81	- 706.38	18,152.31	- 670.23
	0.3	19,986.93	- 686.40	15,961.37	- 648.62
	0.2	18,196.75	- 670.64	14,399.94	- 631.21
	0.1	16,992.69	- 659.14	13,333.69	- 618.40
Logarithmic	0.0	16,277.13	- 651.91	12,676.44	- 609.91
	-0.05	15,984.69	- 649.90	12,482.50	- 607.32
	-0.1	15,984.69	- 648.86	12,374.00	- 605.85
	-0.2	16,100.12	- 650.07	12,406.12	- 606.28
	-0.3	16,632.87	- 655.54	12,774.00	- 611.19
	-0.4	17,599.63	- 665.03	13,507.19	- 620.57
	-0.5	19,085.37	- 678.65	14,657.37	- 634.30
Reciprocal	-1.0	39,459.00	- 800.67	31,397.00	- 762.28
	-2.0	514,192.00	-1,231.98	461,328.00	-1,213.76

NOTE: All TSP values were scaled by a factor 0.1 in preparing this table. Such a scalor transformation will not alter the optimal functional transformation.

1/ $= -\frac{336}{2} \ln \left[\frac{S(\theta: z)}{336} \right]$

2/ $= -\frac{336}{2} \ln \left[\frac{S_{\nu}(\theta: z)}{336} \right]$

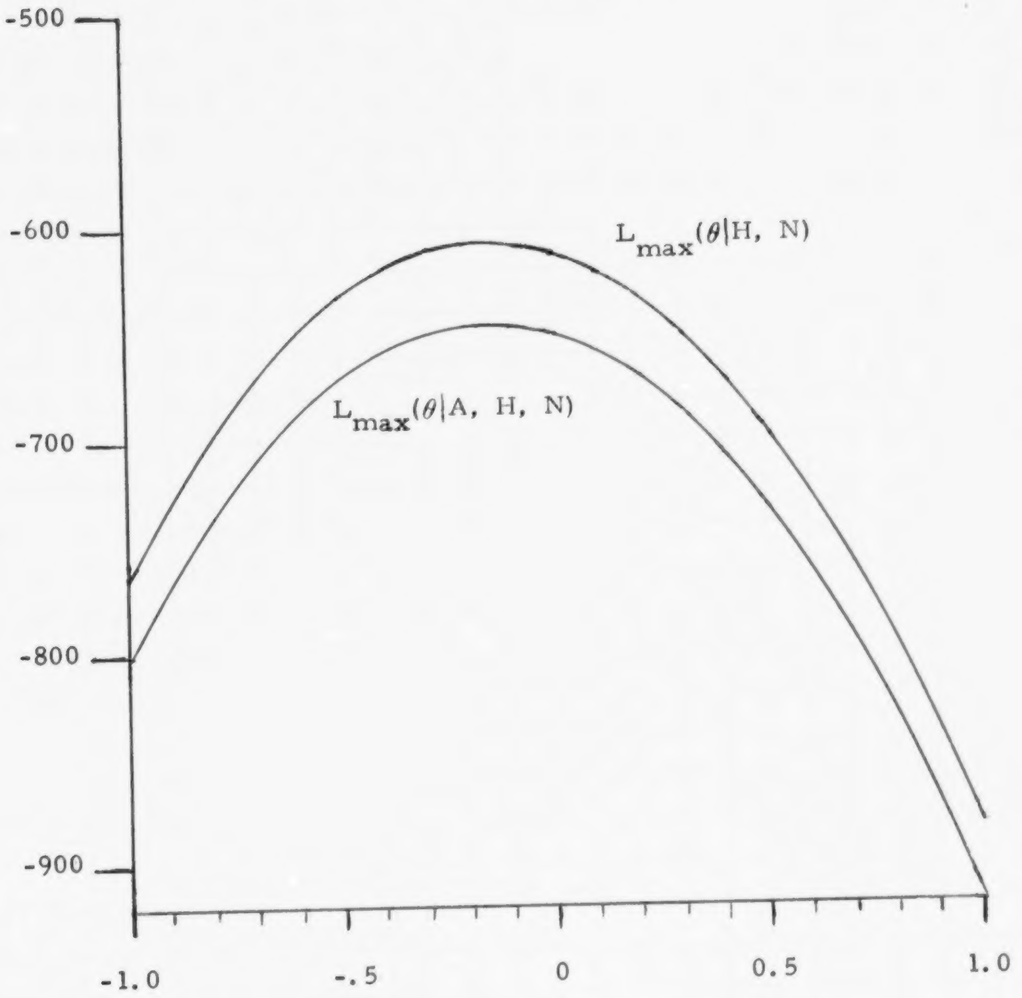


Figure 2. Shape of likelihood surface for selecting transformation. (Data plotted from Table 25.)

TABLE 26. ANALYSIS OF VARIANCE COMPUTATIONS: THREE CANDIDATE OUTLIERS DELETED, TRANSFORMED DATA ($\theta = 0.0$)

Preliminary values	Sums of squares
$C_{ijk\alpha} = \sum_i \sum_j \sum_k \sum_\alpha z^2_{ijk\alpha} = 106{,}712{,}762$	$S_i = C_i - C = 198{,}736$
$C_i = 1/84 \sum_i T^2_{i\cdot\cdot} = 104{,}489{,}072$	$S_j = C_j - C = 344{,}064$
$C_j = 1/112 \sum_j T^2_{\cdot j\cdot} = 104{,}634{,}400$	$S_{ij} = C_{ij} - C_j - C_i + C = 355{,}200$
$C_{ij} = 1/28 \sum_i \sum_j T^2_{ij\cdot} = 105{,}188{,}336$	$S_{\alpha(ijk)} = C_{ijk\alpha} - C_{ijk} = 257{,}344$
$C_{ijk} = 1/7 \sum_i \sum_j \sum_k T^2_{ijk} = 105{,}445{,}680$	$S = C_{ijk\alpha} - C = 2{,}422{,}416$
$C = T^2/N = 104{,}290{,}336$	$S_{k(ij)} = S - S_{\alpha(ijk)} - S_{ij} - S_j - S_i = 1{,}267{,}072$

TABLE 27. ANALYSIS OF VARIANCE TABLEAU: MINES, LOCATIONS RANDOM AND SEASONS FIXED: THREE CANDIDATE OUTLIERS DELETED, TRANSFORMED DATA ($\theta = 0.0$)

Source of estimate	Sum of squares	Degrees of freedom	Mean square	Average value of mean square	Computed f statistics
Between mines	198,736	3	66,245	$\sigma^2+7\sigma_\lambda^2+84\sigma_\xi^2$	8.75*
Between seasons	344,064	2	172,032	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2+112\sigma_\eta^2$	2.91*
Interaction mines X seasons	355,200	6	59,200	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2$	7.82*
Between locations (within mines & seasons)	257,344	34[1]	7,568.94	$\sigma^2+7\sigma_\lambda^2$	1.48
Between replicates (within location, mines & seasons)	1,267,072	248	5,109	σ^2	
Total	2,422,416	293			

[1] $\Sigma pq(v_i-1)$ to reflect missing observations

[2] Adjusted to reflect 45 missing observations

* Denotes significant difference at 0.05 level.

A RETURN TO THE QUESTION OF OUTLIERS

Earlier in the discussion the possibility of outliers in the data was raised. An examination of the untransformed data, see Table 13, suggests as many as three outliers in the data. These values are:

Mine	Season	Location	Replicate #	Numerical Value
1	3	2	2	1600
1	3	2	3	1514
3	2	3	1	1337

The justification for suspicion of these values are the computed values of the standardized residuals. For example, the row mean for total particulates in mine 1, season 3 and location 2 is 635.9 $\mu g/m^3$ (including the candidate outliers 1600 $\mu g/m^3$ and 1514 $\mu g/m^3$). From Table 18, the estimated residual standard error is 26,271 = 162.1. The value 1600 is thus (1600 - 635.9)/162 = 5.95 multiples of the standard error above the row mean. Similar claims can be made for the other candidates.

However, the case for these values as outliers becomes significantly less compelling when the logarithmic transformation is employed. For example, shown below are the replicates in both natural and transformed units:

Natural units, y	559	1600	1514	399	266	80	33
Transformed units $\dot{y} \ln y = z$	740.1	863.12	856.66	700.65	653.21	512.65	409.06

The row mean for the transformed values is 676.49. From Table 28 the standard error among residuals is $\sqrt{5109}$ = 71.48. The standardized residual for the value 1600 in transformed units is (863.12 - 676.49/71.48 = 2.61, much lower than was the case for the untransformed values. (Indeed, the value 33 now has a higher standardized residual.) Similar conclusions follow for the other candidate outliers.

Fortunately, however, the conclusions are insensitive to the outlier question. Replicate analyses on the transformed y values with these candidate outliers deleted (and replaced with corresponding row means 269, 269, 321) results in conclusions which are substantially in

TABLE 28. ANALYSIS OF VARIANCE COMPUTATIONS: THREE CANDIDATE OUTLIERS DELETED, TRANSFORMED DATA ($\theta = 0.0$)

Preliminary values	Sums of squares
$C_{ijk\alpha} = \sum_i \sum_j \sum_k \sum_\alpha z^2_{ijk\alpha} =$ 102,771,392	$S_i = C_i - C =$ 167,744
$C_i = 1/84 \sum_i T^2_{i..} =$ 100,812,304	$S_j = C_j - C =$ 356,368
$C_j = 1/112 \sum_j T^2_{.j.} =$ 101,000,928	$S_{ij} = C_{ij} - C_j - C_i + C =$ 284,896
$C_{ij} = 1/28 \sum_i \sum_j T^2_{ij.} =$ 101,453,568	$S_{\alpha(ijk)} = C_{ijk\alpha} - C_{ijk} =$ 204,304
$C_{ijk} = 1/7 \sum_i \sum_j \sum_k T^2_{ijk} =$ 101,657,972	$S = C_{ijk\alpha} - C =$ 2,126,832
$C = T^2/N =$ 100,644,560	$S_{k(ij)} = S - S_{\alpha(ijk)} - S_{ij} - S_j - S_i =$ 1,113,520

TYPING GUIDE SHEET

agreement with the ANOVA including these values. Tables 28 and 29 show the supporting computations. The only difference of note is the reduction of the F value for the test of differences among locations -- a difference can only be asserted at a lower (but still appreciable) level of significance.

Thus the conclusions do not turn on the question of outliers, so this issue is for practical purposes, irrelevant. Nonetheless, it was important that this was done and the conclusion reached.

This completes the preliminary data analysis. Succeeding sections investigate further the findings and hypotheses suggested by this preliminary analysis. In brief, this further analysis

(1) explores the differences in particulates among samplers at various locations, and,

(2) examines the relationships between observed particulates and activity levels, wind speed and other variables at various mine visits.

DIFFERENCES AMONG SAMPLER LOCATIONS

The results of the analysis of variance support the contention that there were significant differences among sampler locations. This finding is expected on the basis of physical theory - different samplers "see" different emissions inter alia based upon their location relative to sources and the wind direction and speed. In particular, a significant contrast between the "upwind" or ambient sampler and the downwind sampler(s) is anticipated.

To test this hypothesis the data sets of particulates, time sequence, weather conditions and locations were merged and a subset of the observations selected for which clear upwind and downwind samplers existed. Two sets of definitions were used in generating the data sets.

The most restrictive criteria included:

(1) Time coincidence - the sampling periods of each of the three or four samplers must be nearly coincident in time. The "time window" chosen was one hour. That is all paired observations had start times within one hour of each other.

(2) Location relative to mining activities and wind direction - Each sampler was assigned a corresponding ambient sampler if for every hour of sampling one sampler was upwind of all mining activities.

EPA-287 (Cin.)
(4-76)

TABLE 29. ANALYSIS OF VARIANCE TABLEAU: MINES, LOCATIONS RANDOM AND SEASONS FIXED: THREE CANDIDATE OUTLIERS DELETED, TRANSFORMED DATA ($\theta = 0.0$)

Source of estimate	Sum of squares	Degrees of freedom	Mean square	Average value of mean square	Computed f statistic
Between mines	167,744	3	56,915	$\sigma^2+7\sigma_\lambda^2+84\sigma_\xi^2$	9.31*
Between seasons	356,368	2	178,184	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2+112\sigma_\eta^2$	3.75
Interaction mines X seasons	284,896	6	47,483	$\sigma^2+7\sigma_\lambda^2+28\sigma_\beta^2$	7.90*
Between locations (within mines & seasons)	204,304	34[1]	6,009	$\sigma^2+7\sigma_\lambda^2$	1.32
Between replicates (within location, mines & seasons)	1,113,520	245	4,545	σ^2	
Total	2,126,832	290			

[1] $\Sigma pq(v_i-1)$ to reflect missing observations

[2] Adjusted to reflect 45 missing observations

* Denotes significant difference at 0.05 level.

TYPING GUIDE SHEET

(3) Commonality of ambient sampler - A block of three or four time coincident samplers was accepted if all members of the block had the same corresponding ambient sampler.

Since roughly seven samples (approximately one per shift) were taken at each location on each visit to each mine, the possible number of data blocks is 7 x 3 x 4 = 84. If the wind direction were such that there was one ambient sampler, no wind shifts, and data collection always satisfied the time coincidence constraints, 84 data blocks would have resulted. Wind shifts and other factors combined to reduce the number of data points (blocks) that satisfied the above criteria to 21. These are shown in Table 30 and are referred to as "data set 1".

In view of the relatively small number of data points which satisfied the set of criteria, another less stringent set of criteria was employed. This less restrictive set of criteria differed from the first set in that

(1) each sampler was assigned as a corresponding ambient sampler one of the samplers most frequently upwind during the sampling period. No corresponding ambient sampler was assigned, however, if the wind was calm throughout the sampling period or if the modal condition had no sampler ambient. The time coincidence constraint was relaxed from one hour to 0.1 day or 2.4 hours.

The less restrictive rule did permit sampling hours when no sampler was ambient or the wind was variable. To illustrate the differences between the criteria, consider the following examples:

Example 1

Mine 1, Trip 1 - Between 25.96 (earliest start time: decimal day) and 26.33 (latest end time: decimal day) the following observations were recorded:

Sampler Location #	Total Particulates
1	95 $\mu g/m^3$
2	122 $\mu g/m^3$
3	80 $\mu g/m^3$
4	106 $\mu g/m^3$

For every hour in the interval, sampler location 2 was upwind of all mining activities. This block satisfies the more restrictive criteria and is shown as data point 1 on Table 30.

EPA-287 (Cin.)
(4-76)

TABLE 30. UPWIND AND DOWNWIND SAMPLER ANALYSIS DATA SET 1

Observation	Mine	Season	TSP for upwind sampler	TSP for downwind sampler $\mu g/m^3$		
				D1	D2	D3
1	1	1	122	95	80	106
2	1	2	781	304	564	-
3	1	2	72	98	189	-
4	1	2	145	282	204	-
5	1	3	778	1514	649	863
6	1	3	277	399	156	330
7	1	3	69	266	150	51
8	2	1	134	125	178	204
9	2	1	100	58	95	-
10	2	1	143	110	35	-
11	2	2	209	185	184	
12	2	2	63	606	312	-
13	2	2	232	205	164	-
14	2	3	32	95	37	53
15	2	3	49	66	39	21
16	3	2	171	101	1337	
17	3	2	103	178	772	-
18	3	2	121	119	163	-
19	3	2	133	215	221	-
20	3	3	10	17	68	9
21	4	3	50	83	183	90

TABLE 31. PAIRED t TEST ON UPWIND VERSUS DOWNWIND SAMPLER LOCATIONS DATA SET 1 (TRANSFORMED OBSERVATIONS)

Observation	μ_u	μ_d	$\mu_d - \mu_u = \Delta_i$
1	2.501	2.231	- .270
2	4.358	3.723	- .635
3	1.974	2.611	.637
4	2.674	3.177	.503
5	4.354	4.550	.196
6	3.321	3.310	- .011
7	1.932	2.539	.607
8	2.595	2.807	.212
9	2.303	2.005	- .298
10	2.660	1.825	- .835
11	3.040	2.915	- .125
12	1.841	3.772	1.931
13	3.144	2.909	- .235
14	1.163	1.742	.579
15	1.1589	1.330	- .259
16	2.839	3.604	.765
17	2.332	3.613	1.281
18	2.493	2.634	.141
19	2.588	3.082	.494
20	0	.781	.781
21	1.609	2.407	.798

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

Example 2

Mine 3, Trip 3 - Between 19.38 (as above) and 19.99 (as above) the following observations were recorded:

Sampler Location #	Total Particulates
5	65 $\mu g/m^3$
6	33 $\mu g/m^3$
7	204 $\mu g/m^3$
8	110 $\mu g/m^3$

During this time period the following conditions occurred on an hourly basis:

Condition	Fraction of Hours
#6 upwind	.59
#8 upwind	.06
none upwind	.06
wind variable	.29

This block satisfies the less restrictive criteria since sampler #6 was most frequently upwind.

The set of points that satisfy the less stringent criteria include, of course, all of those satisfying the more restrictive criteria, but also permit additional points to be included. These additional points are shown in Table 32 and are referred to as "data set 2". Collectively, data sets 1 and 2 include about half the observations.

Turning now to the question of analysis of results, note first from either data set that, perhaps contrary to expectation, the upwind or ambient sampler is often higher in particulates than some or even all of the downwind samplers. Referring to Table 30, for example, by actual count the ambient sampler had the largest total particulates in 6 cases (29%) and was higher than at least one of the downwind samplers in 14 cases (67%). Similar results were obtained for data set 2. This data shows that variability in so-called background or ambient TSP levels are highly variable and often large in relation to mine-induced emissions. (No implication should be drawn that the mine is 'removing particulates from the air,' though indeed some settling may occur. Rather, the inference is drawn that substantial temporal variability and/or measurement errors exist.) For this reason the

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TABLE 32. UPWIND AND DOWNWIND SAMPLER ANALYSIS
DATA SET 2

Observation	Mine	Season	TSP for upwind sampler	TSP for downwind sampler $\mu g/m^3$		
				D1	D2	D3
1	1	1	497	164	123	-
2	1	2	781	304	564	-
3	1	2	411	531	1600	-
4	1	3	53	75	80	51
5	1	3	77	120	60	106
6	1	3	38	58	36	55
7	2	1	126	-	-	-
8	2	1	134	178	125	204
9	2	1	143	98	95	-
10	2	2	118	294	152	-
11	2	2	92	73	149	-
12	2	3	71	27	38	103
13	3	2	211	273	180	-
14	3	2	121	119	163	-
15	3	2	101	-	396	-
16	3	3	32	72	50	39
17	3	3	28	288	258	17
18	3	3	33	65	110	204
19	4	1	222	-	71	111
20	4	1	92	-	97	230
21	4	3	70	163	95	218
22	4	3	50	185	121	144

TABLE 33. PAIRED t TEST ON UPWIND VERSUS DOWNWIND SAMPLER LOCATIONS
DATA SET 2 (TRANSFORMED OBSERVATIONS)

Observation	μ_u	μ_d	$\mu_d - \mu_u = \Delta_i$
1	3.906	2.653	-1.253
2	4.358	3.723	- .635
3	3.716	4.524	.808
4	1.668	1.908	.240
5	2.041	2.213	.172
6	1.335	1.581	.246
7			
8	2.595	2.807	.212
9	2.660	2.267	- .393
10	2.468	3.051	.583
11	3.219	2.345	.126
12	1.960	1.553	- .407
13	3.049	3.099	.050
14	2.493	2.634	.141
15	2.313	3.679	1.366
16	1.163	1.644	.481
17	1.030	2.380	1.350
18	1.194	2.428	1.234
19	3.100	2.184	- .916
20	2.219	2.704	.485
21	1.946	2.708	.762
22	1.609	2.693	1.084

question of the relative contribution of mining operations to TSP levels is ultimately a statistical one: what differences exist, on average, between ambient and downward locations?

From a statistical point of view there are several possible contrasts which can be tested. One reasonable comparison is the contrast between the TSP of the ambient (upwind) samples and the average of the downwind samplers. Under the null hypothesis that there are no differences between the ambient and downwind samplers, this difference should equal zero.

For reasons advanced earlier in this chapter it is appropriate to use the log transform of the particulates data. Table 31 showed the natural logs of TSP values for the upwind and average (of the logarithms of the) downwind samplers. Since the logs transform induces approximate normality to the TSP values (and the central limit theorem fills in the balance), the paired "t" test is appropriate. The log of the differences Δ_i for each observation is shown also in Table 31. The computed mean and standard deviation of the values for data set 1 are 0.298 and 0.650 respectively. The computed t value is,

$$t = \frac{\overline{\Delta}}{s/\sqrt{N}} = \frac{0.298}{0.650/\sqrt{21}} = 2.10$$

a value which is statistically significant at the $\alpha = 0.05$ level. Thus it can be asserted that the average of the downwind TSPs exceeds the ambient TSP. Based upon data set 1, the mean difference, 0.298, represents a factor exp (0.298) or 1.35. That is, the mean downwind TSP is some 35% higher than ambient conditions.

Similar conclusions emerge if data set 2 is considered. Statistical tests indicate that the observations from data sets 1 and 2 can be pooled, that is the data behave as though they come from the same population (F test on homogeneity of variance, t tests on means). In turn, this pooled data set can be used to compute confidence intervals for the contrast, as detailed in Table 34 following. Based upon the pooled data sets, the downwind samplers differ from the ambient by a mean factor of 1.33 (i.e. 33% higher). The 95% confidence level interval is from 1.079 (7.9% higher) to 1.64 (64% higher). The difference between downwind and upwind samplers helps to explain the ANOVA result identified earlier (the significance between sampler variation). Unfortunately, the sample size of data sets 1 and 2 is too small and not sufficiently evenly distributed to permit an ANOVA to test for main effects of mine and season.

In view of the relatively large ambient TSP levels (in relation to downwind values) it is interesting to explore what relationships, if any, exist between these values and other measured variables. Three variables plausibly correlated with ambient TSP include wind speed, soil moisture and snow cover. Ceteris paribus, the following

TABLE 34. SUMMARY OF RESULTS FOR UPWIND VERSUS DOWNWIND ANALYSIS: TRANSFORMED DATA

Data set	$\bar{\Delta}$	s_Δ	N	t computed	Remarks
1	0.298	0.650	21	2.10	sig.@ .05 level
2	0.273	0.715	21	1.75	sig.@ .10 level
Pooled	0.286	0.675	42	2.75	sig.@ .05 level

95% Confidence limits

$$u = t_{(1-\alpha/2),N} \frac{s_\Delta}{\sqrt{N}} = 2.021 \frac{0.675}{\sqrt{42}} = 0.210$$

Confidence limits 0.286 ± 0.210

or, $[0.076, 0.496]$

in untransformed units:

$e^{0.286} = 1.331$

$e^{0.076} = 1.079$

$e^{0.496} = 1.642$

relationships have been suggested in the literature or might be otherwise expected:

(1) ambient TSP levels are expected to decrease when the ground is snow covered or partially snow covered,

(2) ambient TSP levels are expected to decrease with increasing soil moisture and,

(3) the effect of wind velocity is somewhat more complex,

  (a) on the basis of dispersion considerations from point sources alone, TSP levels are inversely related to wind speed, but

  (b) from either point or area sources, increases in wind speed are expected to be associated with increased emissions.

Figure 3 shows a scattergram on log-log scales of the relationship between TSP and wind speed from data sets 1 and 2. Filled circles denote data points collected when there was no snow cover, while unfilled circles show data where there was snow cover. Though substantial variability exists, there appears to be a strong positive association between TSP and wind speed. Further, in accord with intuition, the presence of snow cover appears to be associated with lower TSP values. On first examination, this latter observation appears to contradict the results of the ANOVA where seasonal effects were not proven to be significant. These findings are not inconsistent, however, for the following reasons:

(1) The ANOVA considered all samplers, not only those that measured upwind or ambient conditions. The foregoing analysis has shown signficant differences between ambient and downwind samplers. Downwind samplers should reflect ambient conditions but also, and more proximately, the activity levels at the various mines. Recall that when one cell was deleted from the ANOVA (mine 1, visit 3) based upon observed high levels of activity and a large interaction effect, the computed seasonal effects became larger. Moreover, the recomputed seasonal effect associated with visit 3 became strongly negative. Visit 3 had snow cover at each mine.

(2) Apart from (1) above, the ANOVA considered samples taken over different shifts as replicate determinations. A consequence of this procedure is that systematic effects (e.g. mine activity levels) are "buried in", and hence inflate, the error term. Thus, it is possible that seasonal effects were present but were not discovered by the ANOVA.

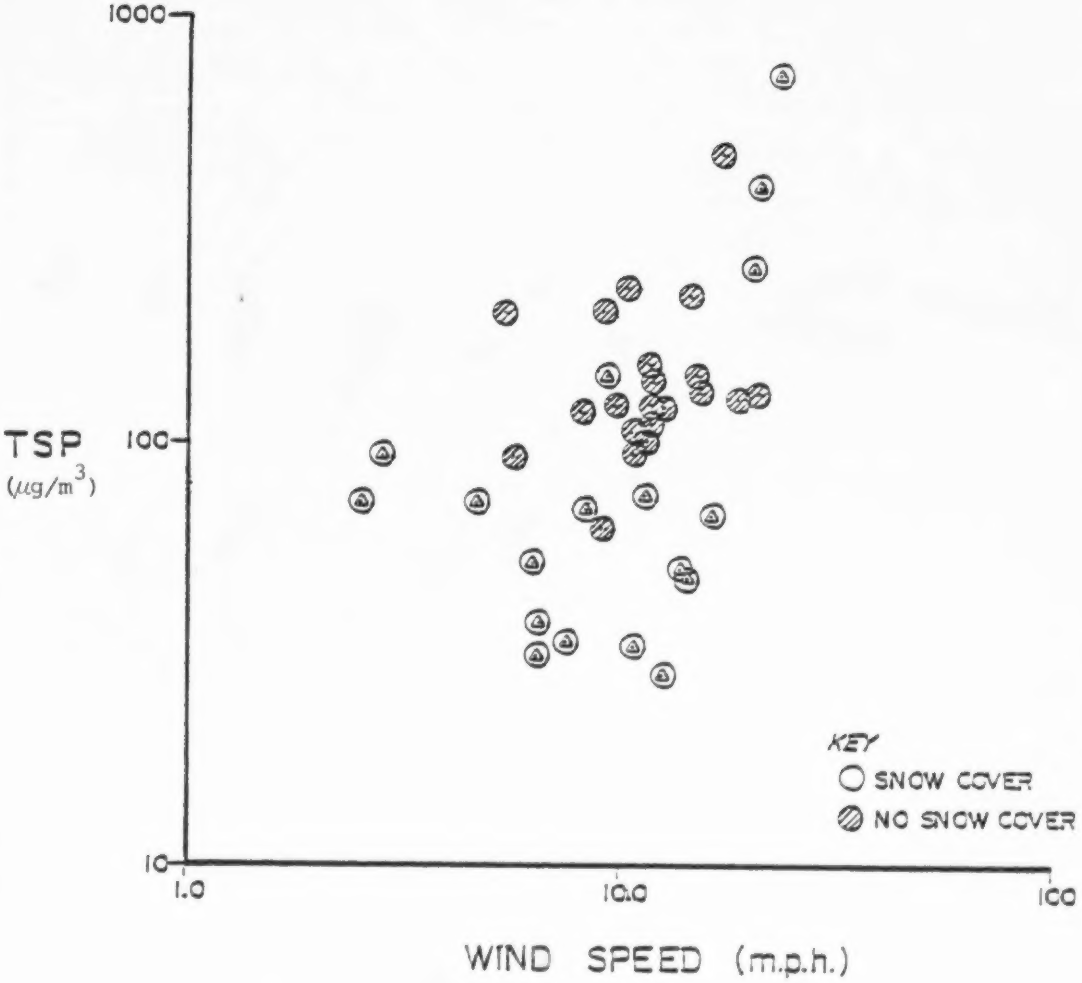


Figure 3. Scattergram (log-log scales) of TSP for ambient samplers: data sets 1 and 2 with outliers deleted.

Of course, the apparent effect of snow cover seen in Figure 3 may simply be an artifact of the data set size (relatively small number of sample points) or distribution (data sets 1 and 2 did not equally reflect all visits to all mines because wind conditions and sampler placement did not result in an "ambient" sampler for all visits).

The impressionistic analysis based upon examination of Figure 3 is also supported by regression analysis on the same data. The coefficient of wind speed in a log-log regression is 0.34, while that for snow (dummy variable, either zero or one) is -0.41, though neither variable is highly significant (t values for 1.33 and 1.66 respectively). The coefficient of multiple correlation was only about 0.35. The effect of the soil moisture variable was also not significant and had negligible predictive power.

To summarize then the results of this section:

(1) ambient and downwind samplers differ significantly, downwind TSP values are some 33% higher and

(2) ambient TSP values appear to be positively correlated with wind speed and negatively correlated with snow cover suggesting that emissions have more operative significance than dispersion - though judgement should be reserved as the predictive power of these variables is not high.

RELATIONSHIP OF TSP TO ACTIVITY LEVELS

This section discusses the results of regression analysis to determine the relationship between observed TSP and activity levels for various mining operations. The dependent variable was taken to be the (logarithm of the) observed TSP value for each sampler. Because of the substantial variability in ambient conditions discussed earlier, no attempt was made to compute the incremental contributions of the mining activity (recall such differences as computed from raw data would often be negative, a consequence of sampling variability). Rather, data from all samplers ambient and downwind alike, for which corresponding activity data was available were used in the analysis.

The independent variables consisted of observations on some twelve activities at the mine operation, including dragline operation, coal haulage, drilling, blasting, loading, scraping and grading, etc. Additionally, wind speed and precipitation were employed in view of their observed or postulated relationships in previous analyses. Table 35 shows a complete listing of the candidate independent variables together with the units of measurement for each. These activities include all dust sources for which emissions factors have been estimated in other studies.

For reasons discussed earlier in the report, a logarithmic transformation was applied to the observed TSP values. This same

TABLE 35. TABLE OF ACTIVITY NUMBERS DEFINITIONS FOR REGRESSION ANALYSIS

Variable name	Operation	Units (all per shift)
Q1	Dragline	Operating minutes
Q2	Coal haulage	Truck trips
Q3	On-mine vehicles	Miles traveled
Q4	Overburden drilling	Operating minutes
Q5	Coal drilling	Operating minutes
Q6	Blasting	Number of holes
Q7	Water trucks	Truck trips
Q8	Vehicles, public roads	Number of vehicles
Q9	Coal loading	Tons
Q10	Coal unloading	Tons
Q11	Scraping	Operating minutes
Q12	Grading	Operating minutes
Speed	Wind speed	M.P.H.
Precip.	Precipitation	Fraction of sampling period during which rain occurred.

transformation has been applied to each of the dependent variables, so that multiplicative relationships of the form

$$y = \beta_o \, Q_i^{\beta_i} \, Q_2^{\beta_2} \, Q_3^{\beta_3} \, \ldots \, Q_n^{\beta_n} ,$$

are being evaluated. Other functional forms such as polynomials were also evaluated. However, in general these gave no better fit to the data and the coefficients of polynomial models are notoriously difficult to interpret (see Mosteller & Tukey Data Analysis and Regression, Chapters 12 and 13). The discussion therefore will center on multiplicative models.

Before proceeding to discuss the regression results in detail it is important to identify some limitations inherent in the regression approach. An awareness of these limitations is essential to a clear understanding of the subsequent data analysis.

In the main, these limitations result from the fact that the experiment was not totally controlled. Some variables, such as the mines to be visited, the visit times and the placement of samplers were controllable. Other important variables, however, such as the level and pattern of mining activity as well as weather were not controllable. Thus, we were limited to passive observation rather than active design. Some consequences endemic to observation rather than design are:

(1) Limited range of observations - It is self-evident that if an independent variable does not change over the observation period, then its effect cannot be determined. Even if it does vary, but only over a limited range, the effect of the variable may be masked by the noise of experimental error. Specifically, it can be shown that the standard error of a regression coefficient $\sigma(\beta_i)$ is of the form,

$$\sigma(\beta_i) = \frac{\sigma}{\left[\sum_{i=i}^{n} (Q_i - \overline{Q})^2 \right]^{1/2}}$$

where

σ = standard deviation of the measurement error

Q_i = values of the independent variable

$\overline{Q}$ = mean of independent variable = $\sum_i Q_i / n$

Note from the above equation that the precision of measurement of the effect of a variable (as $1/\sigma(\beta_i)$) is directly related to the spread (as $(\sum_i (Q_i - \overline{Q})^2)^{1/2}$) or standard deviation of the independent variable. For this reason, a basic maxim of experimental design is to "spread out" the independent variables. Derivatively, the effect of variables with small variability cannot be ascertained with much precision.

Table 36 shows some summary statistics on the mean values and standard deviations (in transformed units) of the independent variables. Several of the variables (Q_4, Q_5, and particularly Q_7) had small $\sigma(Q)$ values. Hence the effects of these variables may not be well determined.

(2) Multicollinearity and shadow variables - Multicollinearity is a word used to describe a situation in which one or more independent variables "move together" or are correlated. If, for example, two independent variables, say Q_1 and Q_2, are perfectly correlated (an exact relation such as $Q_2 = kQ_1$) then it is impossible to "separate out" the effects of each on the dependent variable. Even if the dependence is less than perfect, but still appreciable, then estimation problems remain. The confidence statements about the effect of one variable, for example, must assume a value for each of the others.

In a designed experiment, the independent variables are controlled so as to be orthogonal (i.e. uncorrelated) or nearly so. In an observed experiment, this situation may not be obtained. Table 37 shows simple correlation coefficients between each pair of independent variables (in transformed units). Note that several pairs are highly intercorrelated. The variables Q_{12} (scraping) and Q_{11} (grading) have the highest simple correlation coefficient, 0.69. Other pairs of variables which have relatively high correlation include (please examine Table 35 for definitions of each variable):

Q_3 vs Q_2	0.66
Q_8 vs Q_2	0.65
Q_{12} vs precip.	-0.61
Q_{10} vs Q_9	0.62

TABLE 36. MEANS & STANDARD DEVIATIONS FOR REGRESSION ACTIVITY ANALYSIS (ALL VARIABLES TRANSFORMED AS NATURAL LOGARITHMS)

Variable	Mean	Standard deviation	Ratio of σ/μ	Cases
TSP	2.2555	0.8620	.38	212
Speed	2.0427	0.6919	.34	212
Precip.	-0.0447	0.2252	-5.04	212
Q_1	4.4982	2.3120	.51	212
Q_2	1.8364	1.8816	1.02	212
Q_3	2.9137	1.8121	.62	212
Q_4	0.1221	0.4432	3.63	212
Q_5	0.0380	0.2234	5.88	212
Q_6	0.6309	1.5148	2.40	212
Q_7	0.0078	0.0800	10.35	212
Q_8	0.8687	1.4469	1.67	212
Q_9	1.3722	2.9417	2.14	212
Q_{10}	0.6340	2.0681	3.26	212
Q_{11}	0.5814	1.7428	3.00	212
Q_{12}	0.3582	1.1245	3.14	212

For definition of variables see Table 35.

TABLE 37. SIMPLE CORRELATION COEFFICIENTS FOR ACTIVITY ANALYSIS

	TSP	Speed	Precip	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9
TSP	1.00000	0.37267	-0.04399	0.33047	0.18374	-0.09446	0.06734	0.05016	0.15983	0.03080	0.25042	0.12894
Speed	0.37267	1.00000	-0.04437	-0.02519	0.23671	0.04642	0.03397	-0.06712	0.24327	0.12538	0.18012	0.21294
Precip	-0.04399	-0.04437	1.00000	-0.11504	-0.01726	-0.00218	-0.25808	-0.00353	-0.00992	0.01918	0.11978	-0.42609
Q_1	0.33047	-0.02519	-0.11504	1.00000	0.05363	0.07781	0.06275	-0.07120	-0.05707	0.04096	0.13227	0.22870
Q_2	0.18374	0.23671	-0.01726	0.05363	1.00000	0.66148	-0.27020	-0.16664	0.24311	0.10978	0.64588	0.14317
Q_3	-0.09446	0.04642	-0.00218	0.07781	0.66148	1.00000	-0.44516	-0.27454	-0.02837	0.16484	0.42970	0.02199
Q_4	0.06734	0.03397	-0.25808	0.06275	-0.27020	-0.44516	1.00000	0.55040	0.12389	-0.02662	-0.16622	0.23874
Q_5	0.05016	-0.06712	-0.00353	-0.07120	-0.16664	-0.27454	0.55040	1.00000	-0.06392	-0.01641	-0.10251	-0.06421
Q_6	0.15983	0.24327	-0.00992	-0.05707	0.24311	-0.02837	0.12389	-0.06392	1.00000	-0.04023	0.24637	-0.07123
Q_7	0.03080	0.12538	0.01918	0.04096	0.10978	0.16484	-0.02662	-0.01641	-0.04023	1.00000	-0.05800	0.25028
Q_8	0.25042	0.18012	0.11978	0.13227	0.64588	0.42970	-0.16622	-0.10251	0.24637	-0.05800	1.00000	-0.28140
Q_9	0.12894	0.21294	-0.42609	0.22870	0.14317	0.02199	0.23874	-0.06421	-0.07123	0.25028	-0.28140	1.00000
Q_{10}	0.08091	0.13044	0.01116	0.12839	0.38804	0.29906	-0.08487	-0.05234	-0.04774	0.39006	-0.18494	0.61655
Q_{11}	0.08594	0.01672	-0.43288	0.10273	-0.19062	-0.28988	0.55604	0.55405	0.11674	-0.03222	-0.20123	0.29485
Q_{12}	0.09943	0.07557	-0.61921	0.13908	-0.03186	-0.06552	0.27698	0.17701	0.04313	-0.03420	-0.08510	0.39240

	Q10	Q11	Q12
TSP	0.08091	0.08594	0.09943
Speed	0.13044	0.01672	0.07557
Precip	0.01116	-0.43288	-0.61921
Q_1	0.12839	0.10273	0.13908
Q_2	0.38804	-0.19062	-0.03186
Q_3	0.29906	-0.28988	-0.06552
Q_4	-0.08487	0.55604	0.27698
Q_5	-0.05234	0.55405	0.17701
Q_6	-0.04774	0.11674	0.04313
Q_7	0.39006	-0.03222	-0.03420
Q_8	-0.18494	-0.20123	-0.08510
Q_9	0.61655	0.29485	0.39240
Q_{10}	1.00000	-0.10275	-0.10907
Q_{11}	-0.10275	1.00000	0.68961
Q_{12}	-0.10907	0.68961	1.00000

Note: For definition of each variable see Table 35.

Q_5 vs Q_4	0.55
Q_{11} vs Q_1	0.55

These simple correlation coefficients are of comparable magnitude to the multiple correlation coefficient finally obtained through regression analysis. Multicollinearity then may pose problems for the analysis.

Briefly, the possible consequences of multicollinearity are difficulties in separating out effects of variables, lack of precision in estimation of coefficients and finally sign reversals in the effects of variables. (We shall see that this accounts for a sign reversal in one of the coefficients.)

(3) Issues of uniqueness of estimates - The logic of using a fitting criterion such as minimizing the sum of squares of deviations about a fitted model is clear. It often happens in practice, however, that equations which appear to differ substantially have similar predictive power (the residual sum of squares surface is relatively flat). Best fit equations may therefore differ substantially from the true but unknown relationship.

The foregoing discussion of limitations is not intended as a littany of dispair. Rather, its objective is to provide necessary background for data interpretation. Except for unusual circumstances where field experiments can be fully controlled (e.g. specifying the pattern, intensity and duration of each mining activity), such limitations are likely to characterize all future research. The complexities of data analysis which characterize this research are thus prototypical. As such, the research reported herein anticipates what will occur in subsequent analysis - and is useful if only for this reason.

DETAILS OF REGRESSION RESULTS

The first observation of interest in examining the relationship between mine activity and resulting TSP values is the pattern of simple correlation coefficients. These correlation coefficients are shown in the leftmost column of Table 37. Two points are worth of note: first, with the exception of variable Q_3 (on-mine vehicles), TSP is positively correlated with each of the activity variables. (The only other negative correlation is between TSP and precipitation, a relationship expected on physical grounds.) That is, higher TSP values are associated with higher activity levels, in accord with expectation. The negative correlation between TSP and Q_3 is both unanticipated and, even after the fact, somewhat puzzling. As stated above, such sign reversals could arise because of multicollinearity. The next four sentences may require reading. Suppose, for example, a dependent variable y were directly but weakly proportional to a measured independent variable x_1 and directly and strongly related to an unmeasured (or shadow variable) x_2. Further suppose that x_1 and x_2 are negatively associated (i.e. as x_1 increases, x_2 decreases). A regression of y versus x_1 would show a negative relationship, capturing the dominant effect of the shadow variable x_2. As long as the relationship between x_1 and x_2 remained in effect, the observed correlation between y and x_1 would be satisfactory for predictive purposes - because indeed higher x_1 values would be associated with lower y values - but puzzling nonetheless (if x_2 were not identified as a relevant variable). Now, recall from the ANOVA results that significant differences among mines were shown to exist. Mine 1 in particular had higher TSP values on average. If mine 1 had lower activity levels for the variable Q_3 (on mine vehicles) this might account for the observed negative association between Q_3 and TSP. Additionally, recall that the main effect for season 2 (trip 2) was positive, though (unless mine 1 trip 3 is adjusted) not significantly different from zero. These facts suggest a search for shadow variables (should they exist) might start with consideration of these main effects. Accordingly, dummy variables for mine and season were defined and the correlation between these variables and the activity variables computed. These correlation coefficients are displayed in Table 38. Note from the circled values in Table 38 that indeed Q_3 is indeed inversely related to both the dummy variable for mine 1, shown as DM1 on the printout, and the dummy variable for trip 2, shown as DT2 on the printout. Note also the positive and strong correlations between each of these dummy variables and TSP (a point which emerged from the ANOVA). These facts suggest strongly that the observed negative association between Q_3 and TSP shown in Table 37 is an artifact of the data - reflecting that both mine 1 and trip 2 had lower Q_3 values on average, but overall had higher TSP values. (The use of these dummy variables in the regression is treated in the following section.) This observation resolves the apparent sign reversal evident in Table 37.

The second overall conclusion to be drawn from examination of the simple correlation coefficients shown in Table 37 is that, by and large, the correlation coefficients (r values) are not large. Wind speed has the largest r value, 0.37, followed by Q_1 (the dragline variable) with an r value of 0.33, and Q_8 (vehicles on public roads) with a value of 0.25. All other variables have r values beneath 0.20. The magnitude of these r values suggest that the resulting multiple correlations will not be high or, in physical terms, that either natural variability or unmeasured factors may be significant determinants of TSP levels.

This conjecture is proven correct from an examination of the multiple regression results shown on Table 39. Several stepwise

TABLE 38. ON THE TRAIL OF MULTICOLLINEARITY: SIMPLE CORRELATION COEFFICIENTS BETWEEN DUMMY VARIABLES FOR MINES AND TRIPS AND ACTIVITY VARIABLES

	TSP	SPEED	PRECIP.	01	02	03	04	05	06	07	08	09
Dummy variable mine 1	0.43297	0.15136	0.10238	0.19048	0.23922	-0.11480	-0.18570	-0.11453	0.17690	-0.06479	0.08031	-0.03180
Dummy variable mine 2	-0.24973	-0.20918	-0.12139	0.30368	-0.28107	0.26786	-0.15946	-0.09834	-0.24103	0.16691	-0.34747	0.07654
Dummy variable mine 3	-0.41087	-0.05434	0.08546	-0.83737	-0.12589	-0.07726	-0.11859	-0.07314	-0.04983	-0.04138	-0.25841	-0.20076
Dummy variable trip 1	0.17773	0.17102	-0.30266	0.26743	-0.09727	-0.07738	0.42001	0.25903	-0.06736	0.14654	-0.39576	0.71102
Dummy variable trip 2	0.23725	-0.15990	0.06943	0.15174	0.08201	-0.13475	-0.09635	-0.05942	0.00316	-0.03362	0.18670	-0.16311

NOTE: For definition of column headins, see Table 35.

TABLE 39. A SUMMARY OF SELECTED REGRESSION RESULTS

Data set selected		All observations	All Mine 1	All Mine 2	All Mine 3	All Mine 4	All Trip 1	All Trip 2	All Trip 3
	Multiple correlations coefficient, R	0.58	0.96	0.7[illegible]	0.26	0.4[illegible]		0.62	0.68
	Order variables introduced	S1832	S2189	129	2	638	No significant relationship	S1	S1832
	Functional equation constant term b in natural units	30.3	31	22,756	33.5	135		253	1.33
Coefficients of variables	Dragline, Q1	.13	.10	-1.06				-.33	-.13
	Coal haulage, Q2	.10		-.41	.17				.24
	On-Mine vehicles, Q3	-.16				-.17			-.48
	Drilling, Q5								
	Blasting, Q6					.07			
	Water trucks, Q7								
	Vehicles, public roads, Q8	.10	.46			.18			.17
	Coal loading, Q9		-.18	.03					
	Coalunloading, Q10								
	Scraping, Q11								
	Grading, Q12								
	Wind speed	.40	.68					.83	.19
	Precipitation		-1.02						
Evaluation criteria	Predictive ability	F	E	G	P	P		F	F
	Residuals plots	G	G	F	F	F		F	F
	Signs of coefficients	G	E	P	E	G		G	P
	Applicability to entire data set	All	Ltd. →	→	→	→	→	→	→
	Consistancy with literature	G	G	P	P	P		P	P

regressions are shown on this table, those including all data points, data points from each of the mines taken singly and finally data points for each of the trips taken singly. For each regression, the table gives the coefficient of multiple correlation, R, the coefficients of each of the signficant effects variables, β_i, and finally some qualitative evaluations of the utility of the results. Table 40 shows further details of the regression equation which includes all data points.

This equation including all data points is:

$$TSP = 30.3\ Q_1^{0.13}\ Q_2^{0.10}\ Q_3^{-0.16}\ Q_8^{0.10}\ S^{0.40}.$$

Since, based upon a priori considerations, it is necessary that each of the exponents in the above equation must be greater than or equal to zero, the exponent of Q_3 is set equal to zero, and the resulting relationship becomes,

$$TSP = 30.3\ Q_1^{0.13}\ Q_2^{0.10}\ Q_8^{0.10}\ S^{0.40}.$$

Some idea of the relative leverage of each of the variables in the above equation can be gained by noting, for example, the effect of a doubling of each of these variables. These effects, numerically equal to 100 $(2^{\beta i})$ are shown below:

A Doubling of This Variable	Would Increase TSP Levels By This Percentage
Q_1 (Dragline)	9.4%
Q_2 (Coal Haulage)	7.2%
Q_8 (Vehicles on Public Roads)	7.2%
S (Wind Speed)	32.0%

Evaluated in this manner, windspeed has the greatest leverage.

The regression including all of the data points yielded an R value of 0.58 (see Table 39) - significant in a statistical sense, but which accounts for only $(0.58)^2$ or 34 percent of the variability. Put another way, random effects and exogenous factors together account for some 66% of the variability in observed TSP values. This raises the question "can this variability be explained by other factors?"

Some of the potentially relevant variables not considered in the foregoing analysis include soil moisture (as measured at different

TABLE 40. REGRESSION STATISTICS FOR MODEL SELECTION

```
* * * * * * * * * * * * * * * * * * * * * * * *  M U L T I P L E   R E G R E S S I O N  * * * * * * * * * * * * *   VARIABLE LIST  1
                                                                                                                     REGRESSION LIST  1
DEPENDENT VARIABLE..    Natural logarithm of TSP


MULTIPLE R           0.58365                     ANALYSIS OF VARIANCE     DF      SUM OF SQUARES      MEAN SQUARE            F
R SQUARE             0.34064                     REGRESSION               5.          53.40538         10.68108       21.28507
ADJUSTED R SQUARE    0.32464                     RESIDUAL               206.         103.37303          0.50181
STANDARD ERROR       0.70839

------------------ VARIABLES IN THE EQUATION ------------------        -------------- VARIABLES NOT IN THE EQUATION --------------

VARIABLE            B             BETA      STD ERROR B        F        VARIABLE      BETA IN      PARTIAL   TOLERANCE          F

LNSPEED       0.3948941         0.31698       0.07349      28.875       LNPRECIP     -0.00779     -0.00935     0.94838       0.018
LNQ1          0.1241479         0.33298       0.02135      33.822       LNQ4         -0.04274     -0.04675     0.78869       0.449
LNQ8          0.9348917D-01     0.15693       0.04455       4.403       LNQ5          0.05706      0.06731     0.91735       0.933
LNQ3         -0.1654017        -0.34771       0.03635      20.704       LNQ6         -0.00021     -0.00023     0.83627       0.000
LNQ2          0.1005551         0.21950       0.04194       5.749       LNQ7          0.02134      0.02527     0.92453       0.131
(CONSTANT)    1.106503                                                  LNQ9          0.00938      0.00899     0.60493       0.017
                                                                        LNQ10         0.09255      0.07916     0.48239       1.293
                                                                        LNQ11         0.02155      0.02496     0.88456       0.128
                                                                        LNQ12         0.02796      0.03367     0.95637       0.233


F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION

STATISTICS WHICH CANNOT BE COMPUTED ARE PRINTED AS ALL NINES.
```

locations), other weather factors such as stability class and finally qualitative or categorical site-specific variables such as the topography, nature and extent of vegetative cover, areas exposed to wind erosion and soil type at each mine. Additional regressions were conducted to screen these variables.

The first set of runs included soil moisture and stability class in addition to the activity variables measured earlier. Instances of missing data for these variables were sufficiently numerous that when the resulting reduced data set was employed, the overall multiple correlation (adjusted for degrees of freedom) was lower. Therefore, the search for explanation continued.

Dummy variables for mines and seasons were defined in an attempt to capture the effects of site-specific variables such as those referred to above (e.g. topography, wind erosion area, etc.). The regression results and analysis of variance are shown in Table 41. As can be seen, inclusion of these variables improves the multiple correlation coefficient somewhat, from 0.58 to 0.65. However, the site and trip-specific variables now dominate the relationship - only the effect of wind speed remains roughly constant. The effect of Q_{12} (vehicles on public roads) is somewhat smaller than before, and all the other activity variables disappear from the equation! In a predictive sense, this equation is only slightly to be preferred to the relationship in Table 40, and this relationship does not highlight the effects of activity variables. For this reason, the activity analysis is to be preferred. Taken together, however, these results suggest that qualitative site-specific variables are at least as important if not of greater significance than the identified activity variables.

THE DISTRIBUTION OF PARTICLE SIZE

The final point discussed in this chapter concerns the distribution of particle size. All the foregoing analyses have been conducted on aggregated or TSP values. Similar analyses could be conducted on any of the four size ranges of particles. The data analysis strategy might well parallel that shown here. It may, however, prove difficult to extract significant correlations from the disaggregated data. This is because 'signal to noise' ratio of this disaggregated data is somewhat lower. Raw data in disaggregated form is shown in the appendix.

TABLE 41. REGRESSION OUTPUT FOR COMBINED ACTIVITY AND SITE- AND SEASON-SPECIFIC ANALYSIS

```
* * * * * * * * * * * * * * * * * * * * * * * *   M U L T I P L E   R E G R E S S I O N   * * * * * * * * * * * * *

DEPENDENT VARIABLE..   Natural logarithm of TSP


MULTIPLE R            0.65148                     ANALYSIS OF VARIANCE    DF      SUM OF SQUARES        MEAN SQUARE            F
R SQUARE              0.42493                     REGRESSION               6.          66.54085           11.09014         25.19437
ADJUSTED R SQUARE     0.40758                     RESIDUAL               205.          90.23756            0.44018
STANDARD ERROR        0.66346

------------------ VARIABLES IN THE EQUATION ------------------         -------------- VARIABLES NOT IN THE EQUATION --------------

VARIABLE          B               BETA      STD ERROR B       F          VARIABLE     BETA IN     PARTIAL   TOLERANCE        F

DM1          0.3197476         0.18293      0.13175        6.650        INPRECIP     0.02242     0.02302    0.60630        0.108
LNSPEED      0.3670659         0.29464      0.07121       26.569        LNQ1         0.11084     0.07791    0.28438        1.246
DM3         -0.8489912        -0.35791      0.14804       32.889        LNQ2        -0.04384    -0.05312    0.85143        0.582
DM2         -0.3969786        -0.19989      0.12819        9.590        LNQ3        -0.04293    -0.05356    0.89575        0.587
DT2          0.3262127         0.11797      0.16878        3.736        LNQ4        -0.00102    -0.00117    0.76149        0.000
LNQ12        0.8061353D-01     0.10516      0.04356        3.425        LNQ5         0.03747     0.04665    0.89279        0.445
(CONSTANT)   1.563865                                                   LNQ6        -0.01708    -0.02119    0.88591        0.092
                                                                        LNQ7         0.03405     0.04339    0.93454        0.385
                                                                        LNQ8         0.01193     0.01259    0.64064        0.032
                                                                        LNQ9        -0.00851    -0.00984    0.77049        0.020
                                                                        LNQ10        0.00473     0.00581    0.86978        0.007
                                                                        LNQ11        0.02892     0.02610    0.86893        0.139
                                                                        DT1          0.02571     0.02761    0.66365        0.156

F-LEVEL OR TOLERANCE-LEVEL INSUFFICIENT FOR FURTHER COMPUTATION

STATISTICS WHICH CANNOT BE COMPUTED ARE PRINTED AS ALL NINES.
```

BIBLIOGRAPHY

Allen, John R. Physical Process of Sedimentation; An Introduction. George Allen and Unwin Ltd., London, 1970. pp. 92-117.

American Society for Testing and Materials. ASTM Standards on Methods of Atmospheric Sampling and Analysis, Philadelphia, Pennsylvania, 1962.

Ash, D. On the Statistical Analysis of Air Pollution Data. Tech. Report 19, Department of Statistics, Princeton University, New Jersey, 1972.

Axetell, K. Survey of Fugitive Dust from Coal Mines. PEDCo - Environmental, Inc., Cincinnati, Ohio, 1978.

Bagnold, R. A. The Physics of Blown Sand and Desert Dunes. Methuen and Company, London, 1954.

Barrett, Larry B. and Thomas E. Waddell. Cost of Air Pollution Damage, A Status Report. National Environmental Research Center, EPA, Research Triangle Park, North Carolina, 1973.

Bennett, C. A. and N. L. Franklin. Statistical Analysis in Chemistry and the Chemical Industry. John Wiley and Sons, New York, 1963.

Beryland, M. E., Ed. Air Pollution and Atmospheric Diffusion. John Wiley and Sons, New York, 1973. pp. 129-133. Translated from Russian by H. Olacu.

Box, G. E. P. and Cox. An Analysis of Transformations. Journal of the Royal Statistical Society, London, 1964. pp. 211 et seq.

Busse, Adrian and Zimmerman, John. User's Guide to the Climatological Dispersion Model. E.P.A., Research Triangle Park, North Carolina, 1973.

Cadle, Richard D. The Measurement of Airborne Particles. John Wiley and Sons, New York, 1975.

Chamberlain, A. C. 1966. Transport of Lycopoduim Spores and Other Small Particles to Rough Surfaces. Proc. R. Soc. A 296. pp. 45-70.

Cheremisnoff, P. N. and Angelo C. Morresi. "Predicting Transport and Dispersion of Air Pollutants from Stacks". Pollution Engineering. pp. 26-30.

Chernoff, Herman. "Sequential Analysis and Optimal Design". Regional Conference Series in Applied Mathematics, SIAM, Philadelphia, Pennsylvania, 1972.

Clough, W. S. 1975. The Deposition of Particles on Moss and Grass Surfaces. Atmospheric Environment. pp. 1113-1119.

Cowherd, C., Jr., K. Axetell, Jr., C. M. Guenther, and G. A. Jutze. Development of Emissions Factors for Fugitive Dust Sources. Midwest Research Institute, Kansas City, Missouri. Prepared for Environmental Protection Agency, Research Triangle Park, North Carolina, under Contract No. 68-02-0619. Publication No. EPA-450/3-74-037. June, 1974.

Crawford, Jay and James K. Miller. Determination of Particulate Emission Factors from Lignite Mining Operations. Division of Env. Eng., North Dakota State Department of Health, Bismark, North Dakota, 1976.

Daniel, C. Patterns in Residuals in the Two-Way Layout. Technometrics, Vol. 20 #4, 1978. pp. 385 et seq.

Dego, J., J. Toma, R. B. King. Development and Testing of a Portable Wind Sensitive Directional Air Sampler. JAPCA, Vol. 27, 1977. pp. 142-144.

Dunbar, David R. Control Techniques for Particulate Emissions from Unpaved Roads, Agricultural Activities and Construction. Presented at the 67th Annual Meeting of the Air Pollution Control Association, Denver, Colorado, 1974.

Environmental Research and Technology. Air Pollutant Emissions in the Northwest Colorado Coal Development Area. Environmental Research and Technology, Westlake Village, California, 1975.

Faith, W. L. An Evaluation of Fugitive Dust Emissions. Presented at the 67th Annual Meeting of the Air Pollution Control Association, Denver, Colorado, 1974.

Fennelly, Paul F. "The Origin and Influence of Airborne Particulates". American Scientist, Vol. 64, 1976. pp. 46-56.

General Metal Works. Operator's Manual, Model GMWL 2000 H. General Metal Works, Inc., Cleveland, Ohio, 1977.

Harrington, R. E. "Fine Particulates -- The Misunderstood Air Pollutant". Journal Air Pollution Control Association, Vol. 24, 1974. pp. 927-929.

Herrick, Robert A. "Recommended Standard Method for Continuing Dust Fall Survey (APM-1, Revision 1)". JAPCA, Vol. 16, 1966. pp. 372-377.

HEW. Air Quality Criteria for Particulate Matter. Public Health Service, NAPCA Pub. AP-49, 1969.

HEW. Characteristics of Particulate Patterns. National Air Pollution Control Administration, Raleigh, North Carolina, 1970.

HEW. Handbook of Air Pollution. National Center for Air Pollution Control, Durham, North Carolina.

Hittman Associates. Environmental Impacts, Efficiency, and Cost of Energy Supply and End Use. Volume I. Hittman Associates, Incorporated, Columbia, Maryland. Prepared for Council on Environmental Quality, National Science Foundation, and U.S. Environmental Protection Agency, 1974.

Holzworth, George C. Mixing Heights, Wind Speeds and Potential for Urban Air Pollution Throughout the Contiginous U.S. EPA Office of Air Programs, Research Triangle Park, North Carolina, 1972.

Jutze, G. A., K. Axetell, Jr., and W. Parker. Investigation of Fugitive Dust-Sources Emissions and Control. PEDCo Environmental Specialists, Inc., Cincinnati, Ohio. Prepared for Environmental Protection Agency, Research Triangle Park, North Carolina, under Contract No. 68-02-0044. Publication No. EPA-450/3-74-03a. June, 1974.

Katz, M. Measurement of Air Pollutants. World Health Organization, Geneva, Switzerland, 1969.

Kolnsberg, H. Technical Manual for the Measurement of Fugitive Emissions. The Research Corporation of New England, Weatherfield, Connecticut, 1976.

Larsen, Ralph I. "A Mathematical Model for Relating Air Quality Measurements to Air Quality Standards". U.S.E.P.A. Pub. AP-89, Research Triangle Park, North Carolina, 1971.

Lillis, J. and Dexter Young. "EPA Looks at Fugitive Emissions". JAPCA, Vol. 25, 1975. pp. 1015-1018.

Lundgren, Dale A. and Harold J. Paulus. JAPCA, Vol. 25, 1975. pp. 1227-1231.

Mathtech. Evaluation of Current Surface Coal Mining Overburden Handling Techniques and Reclamation Practices. Report prepared for U.S. Department of the Interior, Bureau of Mines, Washington, D.C., 1976.

McMullen, R. Gene. "Ambient Air Programs -- An Inaccurate Measurement". Presented at the 17th National Symposium of the Analysis Instrumentation Division of the Instrument Society of America, April 21-22, 1971.

McNeal, W., et al.. 1978 Keystone Coal Industry Manual. McGraw-Hill, New York, 1978.

Monsanto Research Corporation. Fugitive Dust from Mining Operations. Final Report. Dayton, Ohio. Prepared for W.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1975.

Mosteller, F. and J. W. Tukey. Data Analysis and Regression. Addison Wesly, Reading, Massachusetts, 1977.

Noll, Kenneth E. and Terry L. Miller. Air Monitoring Survey Design. Ann Arbor Science, Ann Arbor, Michigan, 1977.

Padmanabhamurtz, B. "The Role of Wind in Pollution Dispersion". JAPCA, Vol. 25, 1975. pp. 956-957.

Patterson, E. M. and D. A. Gillette. 1977. Measurements of Visibility vs. Mass Concentration for Airborn Soil Particles. Atmospheric Environment, 11. pp. 193-196.

Pasquill F. Atmospheric Diffusion. 2nd Edition, John Wiley and Sons, New York, 1974.

PEDCo Environmental Specialists, Inc. Evaluation of Fugitive Dust Emissions from Mining. Tasks 1, 2, and Final Reports. Prepared for U.S.E.P.A., Cincinnati, Ohio, 1976.

Research Corporation of New England. Technical Manual for Measurement of Fugitive Emissions: Upwind/Downwind Sampling Method. Prepared for U.S.E.P.A., Research Triangle Park, North Carolina, 1976.

Roberts, John W. and Harry A. Watters. Cost and Benefits of Road Dust Control in Seattle's Industrial Valley. Presented at the 67th Annual Meeting of the Air Pollution Control Association, Denver, Colorado, 1974.

Scales, J. W. Air Quality Instrumentation. Instrument Society of America, Pittsburgh, Pennsylvania, 1977.

Sehinel, G.A. Experimental Measurements and Predictors of Particle Deposition and Resuspension Rates. Batelle, Pacific Northwest Laboratory, 1975.

Scorer, Richard S. Air Pollution. Pergamon Press, New York, 1968.

Smith, F. and D. Wagoner. Guidelines for Development of a Quality Assurance Program. Vol. 4 - Determination of Particulate Emissions for Stationary Sources. Triangle Research Park, North Carolina, 1974.

Stern, Arthur C. Air Pollution. Volumes I, II, and III, Second Edition, Academic Press, New York, 1968.

Thornthwaite, C. W. Climates of North America According to a New Classification. Geograph. Rev. 21:633-655, 1931.

Turner, D. Bruce. Workbook of Atmospheric Dispersion Estimates. U.S. HEW, Public Health Service Pub. 999-Ap-20, 1970.

U.S. Department of Commerce. Technical Manual for Measurement of Fugitive Emissions. Prepared for Industrial Environmental Research Laboratory by the Research Corporation of New England, 1976.

U.S. Environmental Protection Agency. Surface Coal Mining in the Northern Great Plains of the Western United States. Denver, Colorado, 1976.

U.S. Environmental Protection Agency. Compilation of Air Pollutant Emission Factors. Second Ed. Research Triangle Park, North Carolina. Pub. No. AP-42, 1975.

U.S. Environmental Protection Agency. Development of Emission Factors for Fugitive Dust Sources. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Pub. No. EPA-450/3-74-037, 1974.

U.S. Environmental Protection Agency. Environmental Protection in Surface Mining of Coal. U.S. Environmental Protection Agency, Cincinnati, Ohio. Pub. No. EPA-670/2-74-093, 1974.

U.S. Environmental Protection Agency. Investigation of Fugitive Dust -- Sources, Emissions, and Control. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Pub. No. EPA-450/3-74-036, 1974.

U.S. Environmental Protection Agency. Supplement No. 5 for Compilation of Air Pollutant Emission Factors. Second Edition. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 1975.

U.S. Environmental Protection Agency. User's Guide for the Climatological Dispersion Model. Research Triangle Park, North Carolina, 1973.

U.S. Department of the Interior. (Unpublished) Environmental Impact Statement for Northwest Colorado Coal Development. Bureau of Land Management, Denver, Colorado.

Wang, I. T. and D. M. Rote. "A Finite Line Source Dispersion Model for Mobile Source Air Pollution". JAPCA, Vol. 25, 1975. pp. 730-733.

Woodruff, N. P. and F. W. Siddoway. "A Wind Erosion Equation". Soil Science Society of American Proceedings, Vol. 29, 1965.

APPENDIX A

MINE MAPS

The first figure in the appendix shows the legend used on the maps. Following that are the maps themselves, one for each of three visits to each of four mines.

Mines 2 and 3 represent different pit areas of the same mine. On some visits, only one weather station was used for both areas.

LEGEND

⊠	Dragline
▲	Coal Loader
●	Coal Drill
○	Overburden Drill
△	Shovel
◊	Sampler
✚	Soil Moisture Collectors
◘	Loading Facility (Tipple)
⬬	Weather Station
▣	Blasting
▒	Reclamation Activity
▤	Grading Activity
░	Topsoil Removal Activity
▬	Coal Unloading Activity
▨	Unvegetated Areas
■	Exposed Coal
— — —	Paved Public Road
- - - - -	Unpaved Public Road
———	Haul Road - In use
···········	Haul Road - Not in use
-·—·-	Secondary Roads
—-—	Scraper Road

Figure A-1. Legend for mine maps.

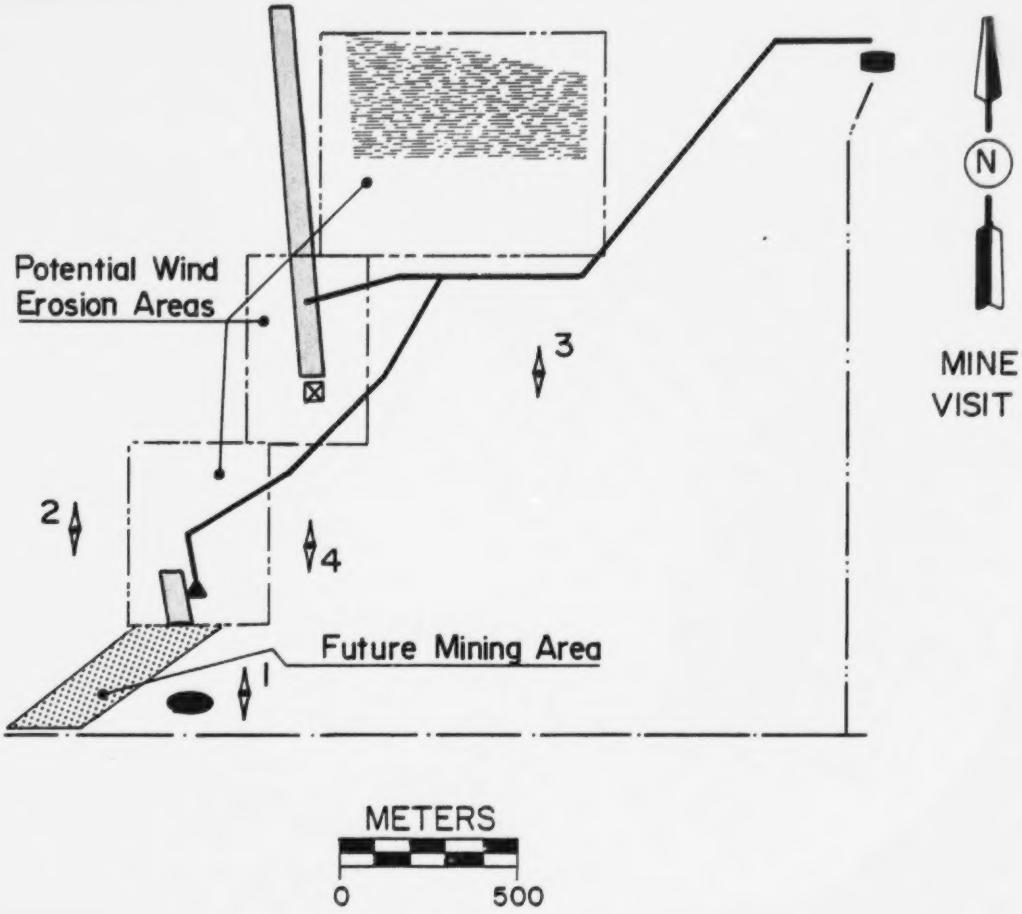


Figure A-2. Map for mine 1, visit 1.

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTION HERE

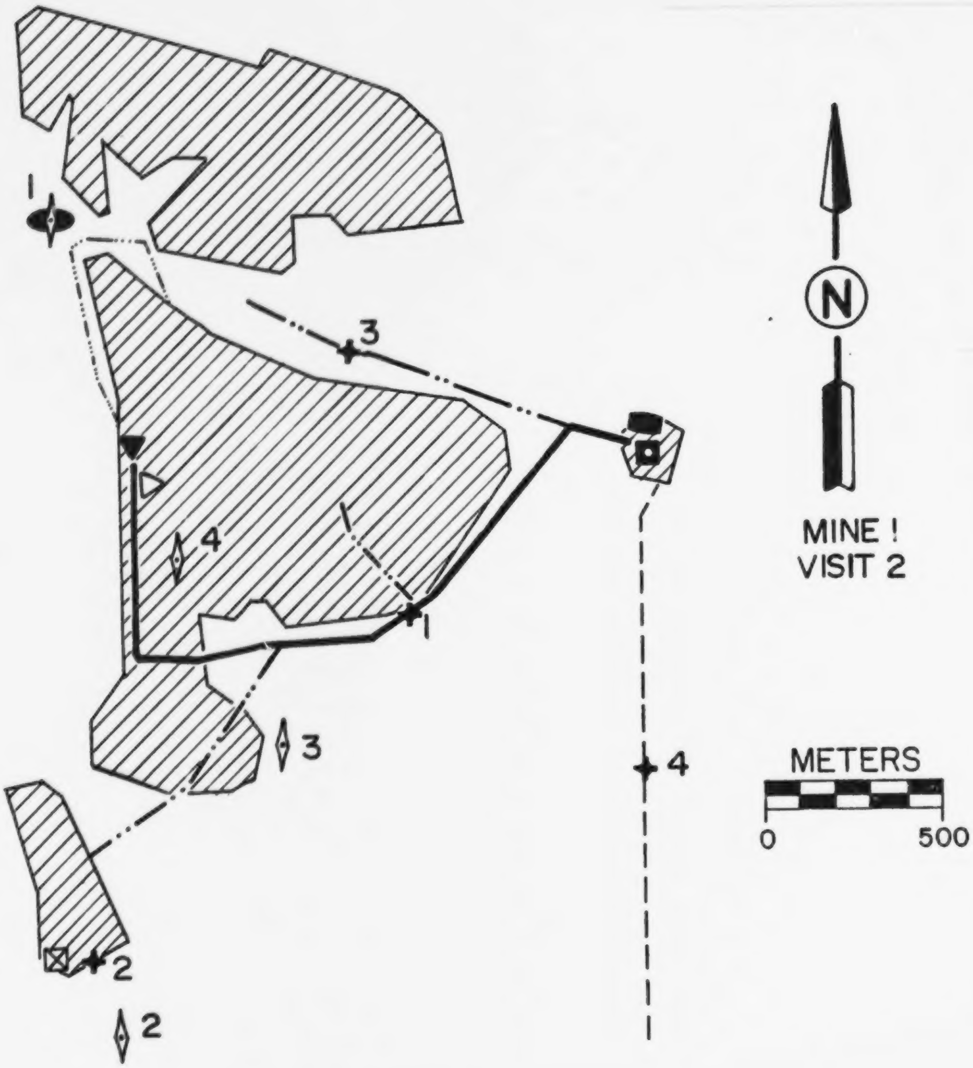


Figure A-3. Map for mine 1, visit 2.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA (OUTSIDE DIMENSION FOR TABLES AND FIGURE CAPTIONS)

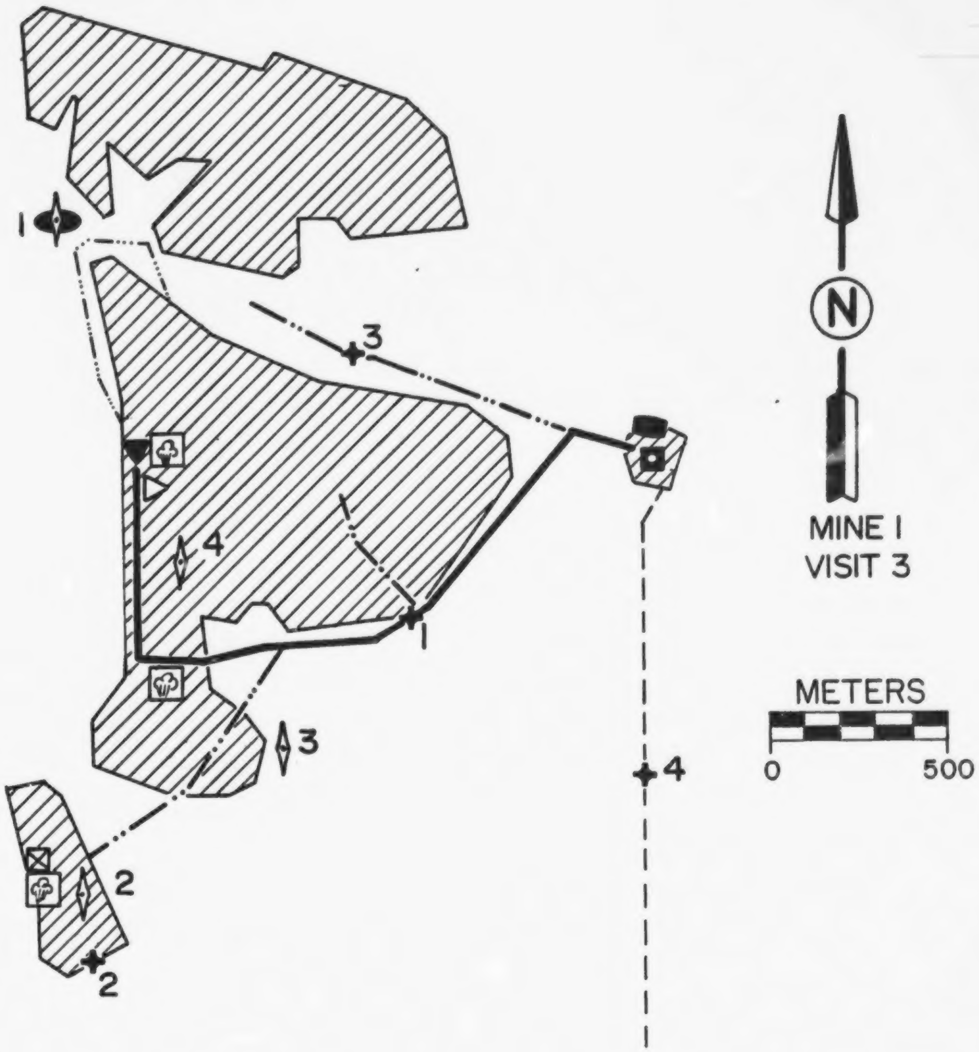


Figure A-4. Map for mine 1, visit 3.

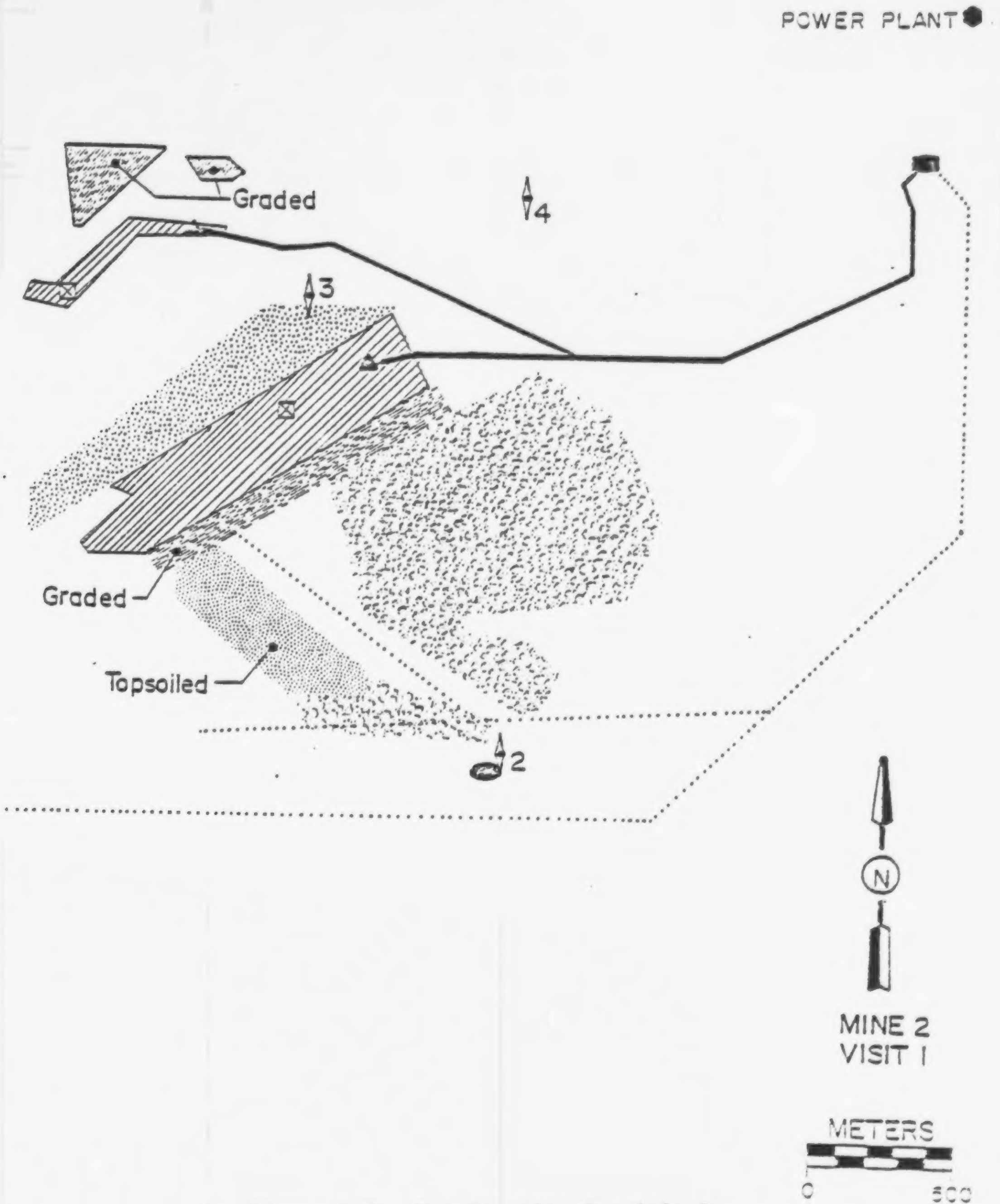


Figure A-5. Map for mine 2, visit 1.

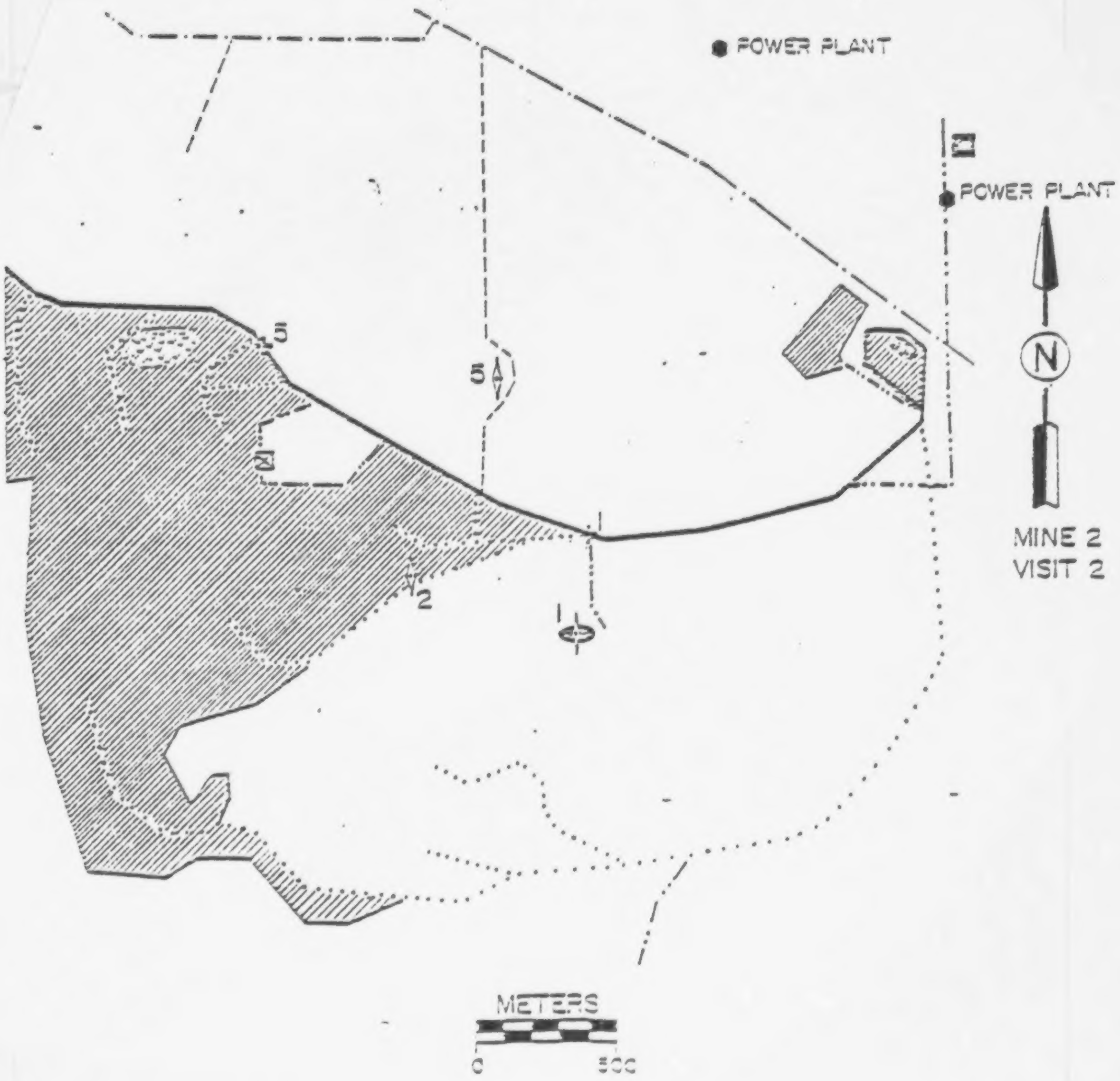


Figure A-6. Map for mine 2, visit 2.

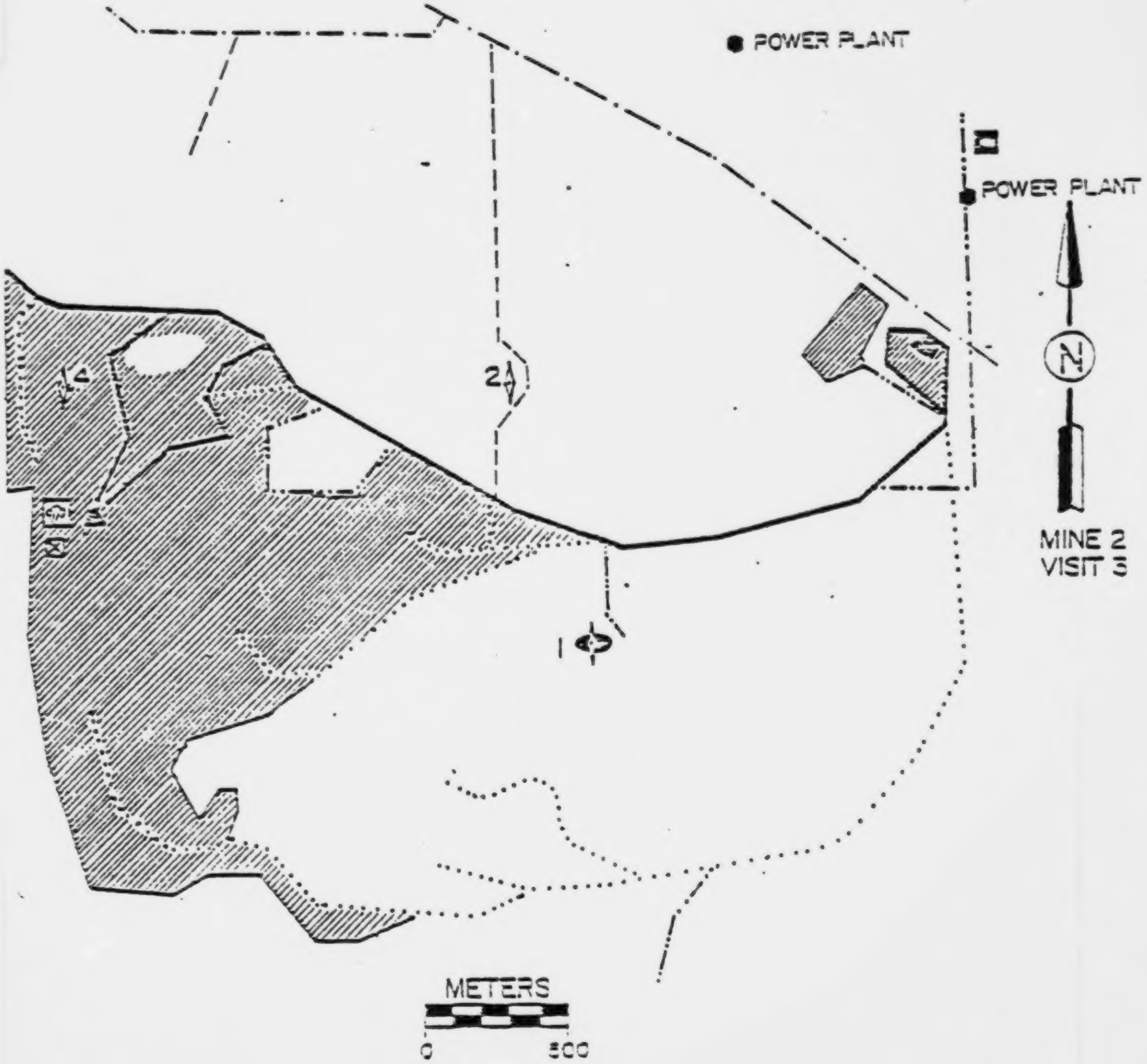


Figure A-7. Map for mine 2, visit 3.

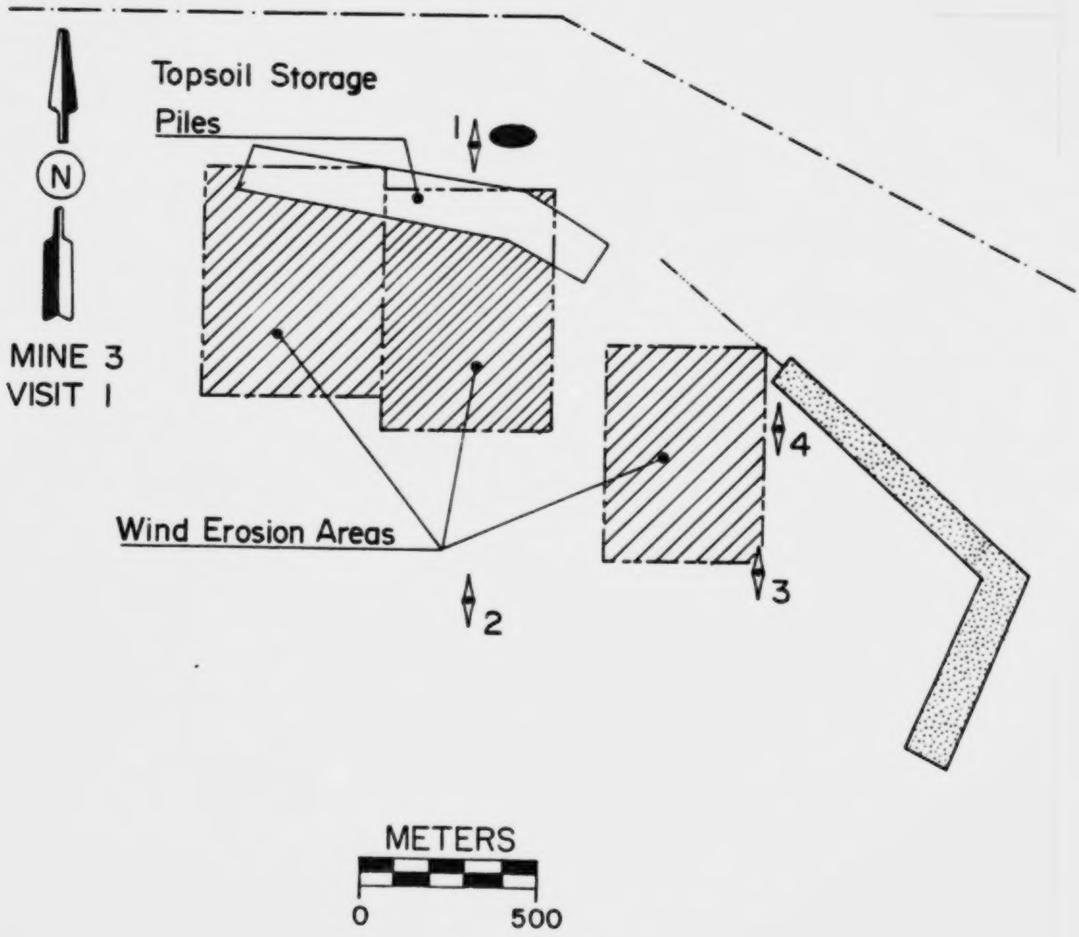


Figure A-8. Map for mine 3, visit 1.

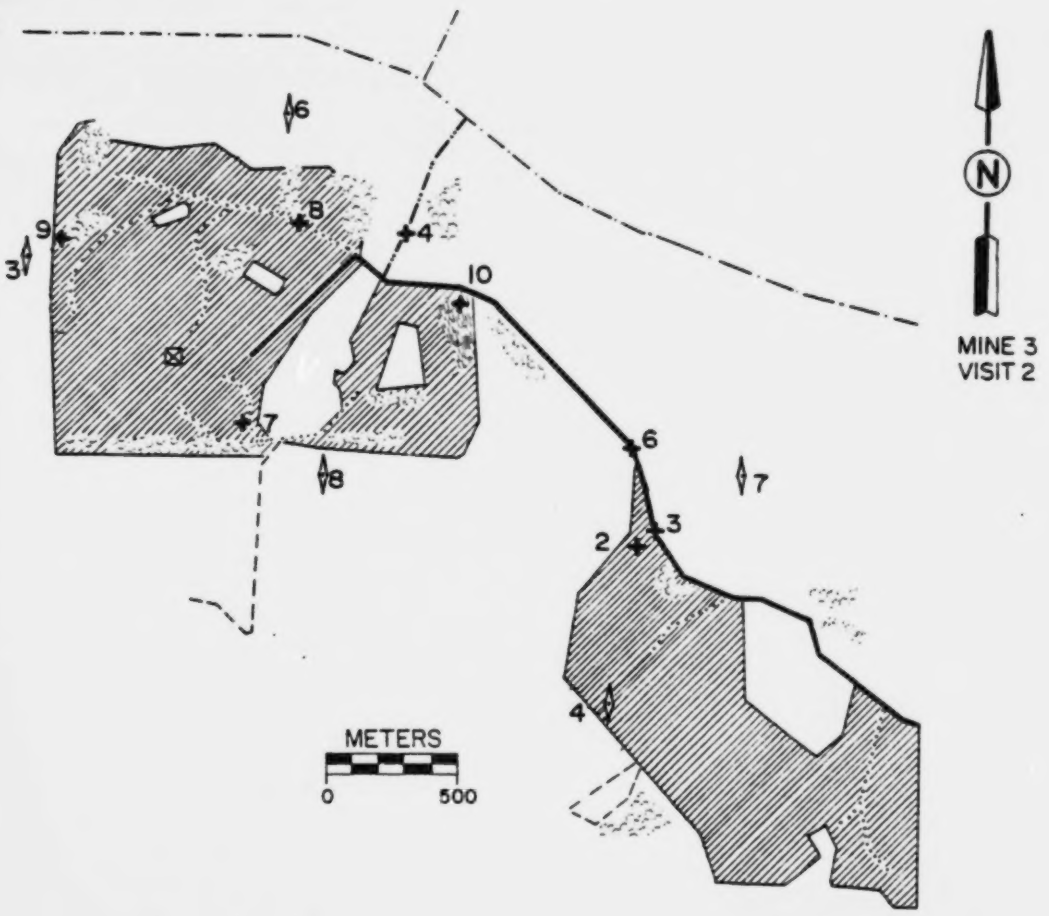


Figure A-9. Map for mine 3, visit 2.

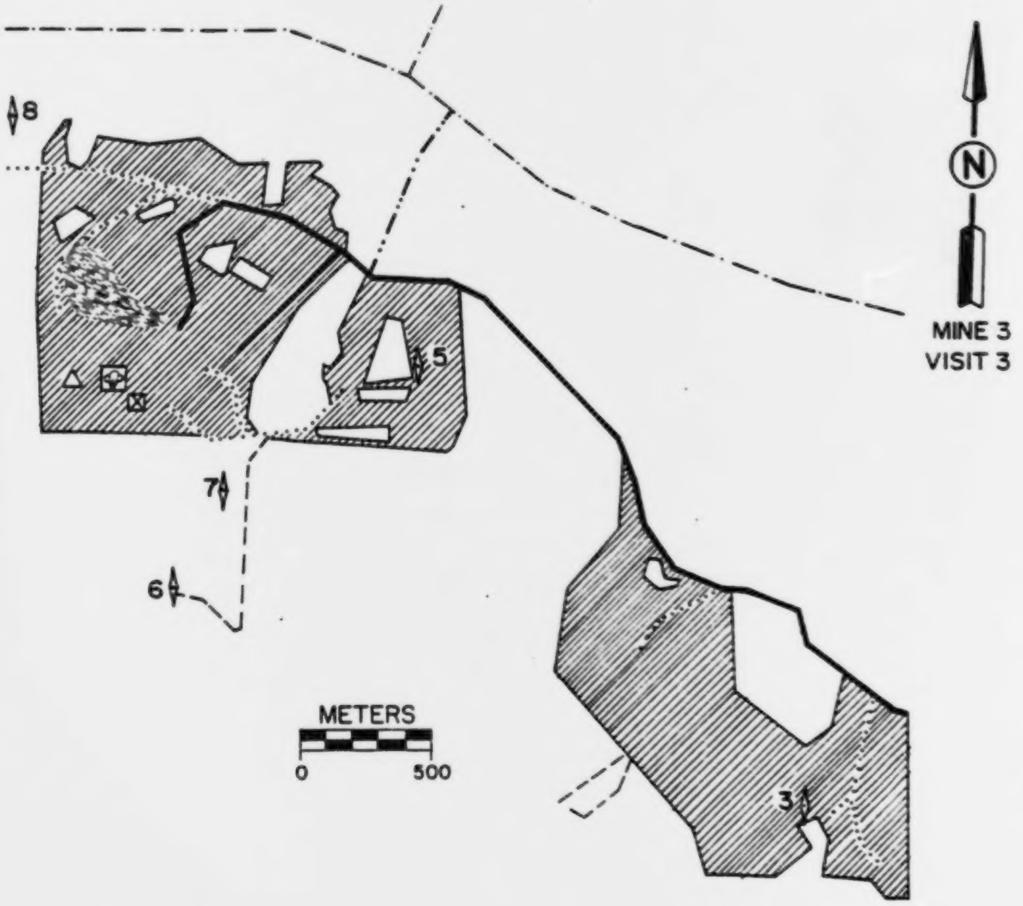


Figure A-10. Map for mine 3, visit 3.

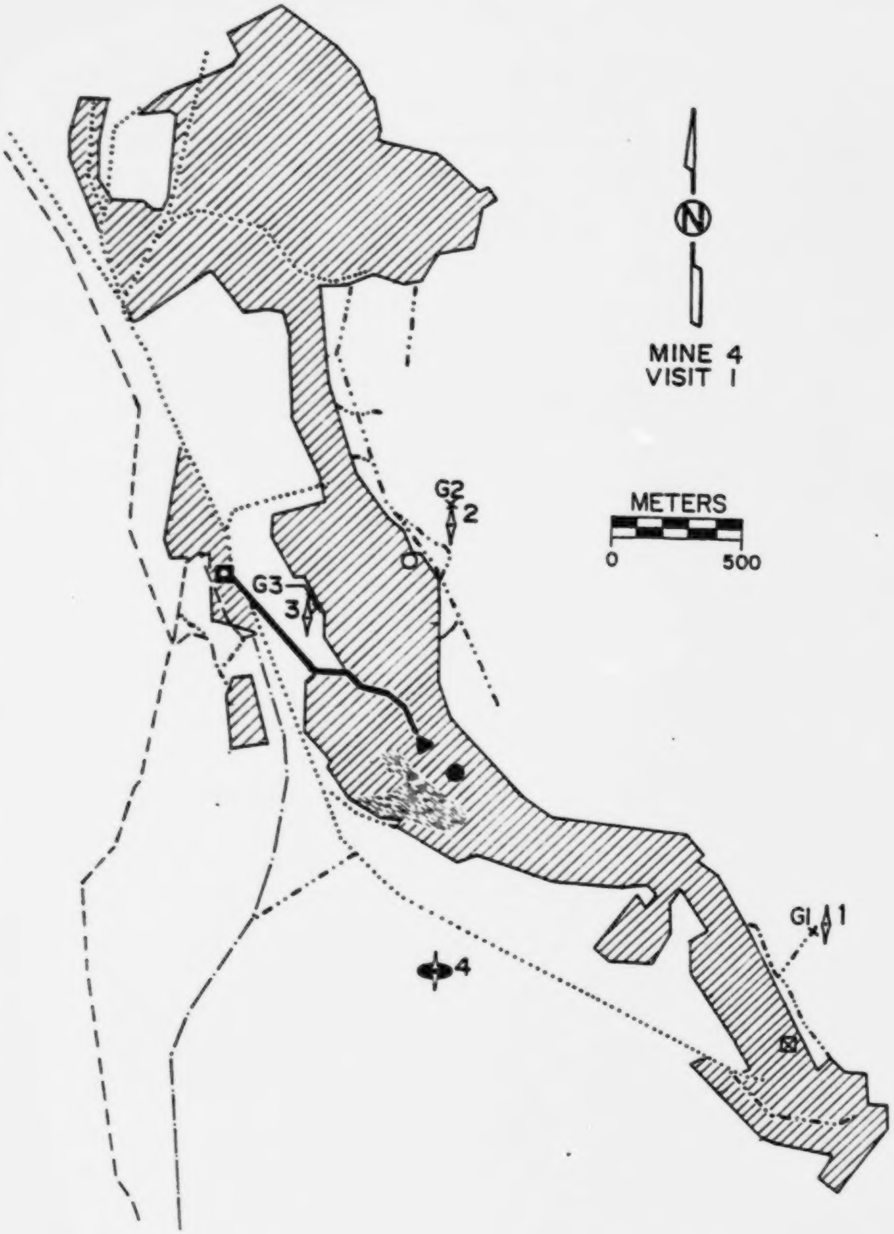


Figure A-11. Map for mine 4, visit 1.

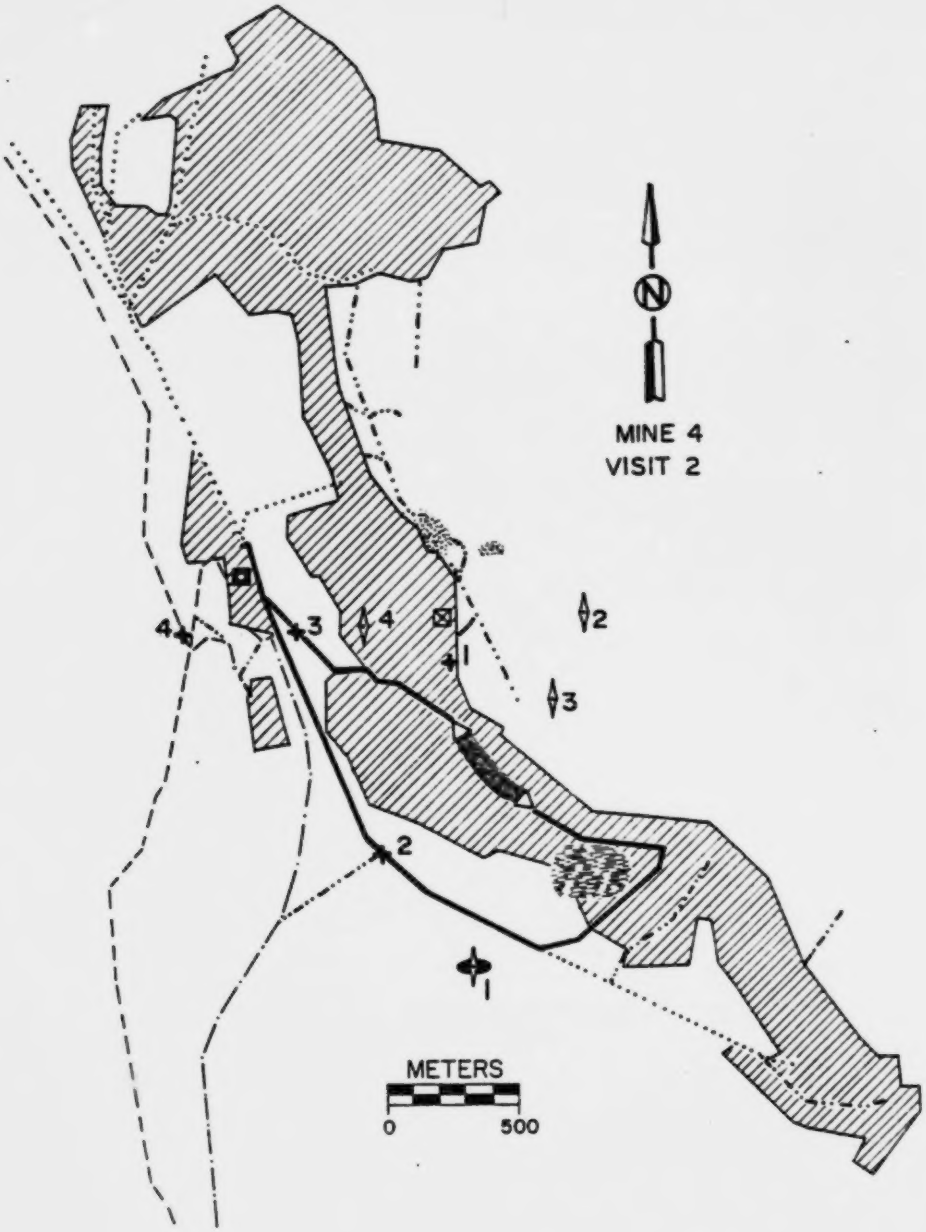


Figure A-12. Map for mine 4, visit 2.

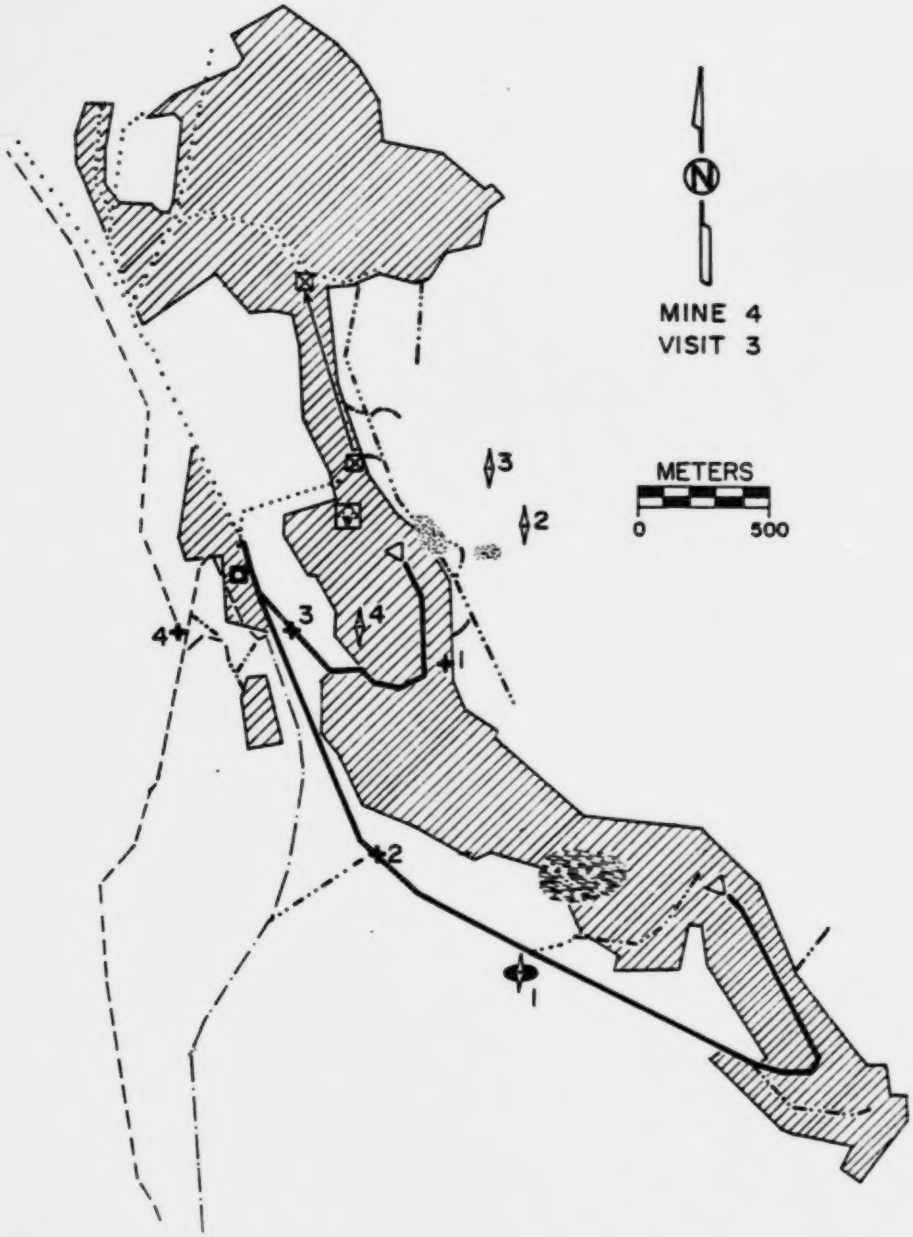


Figure A-13. Map for mine 4, visit 3.

APPENDIX B

COORDINATE GEOMETRY

The following distance and angle formulas were derived for use in data analysis. They are based on the assumption that samplers and sources are located at the same height. Point, line, and area sources are considered.

POINT SOURCE

Consider a point dust source with coordinates $D(x_1, y_1)$ and a sampler with coordinates $S(x_2, y_2)$. The distance between them is given by

$$d = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

To find the angle α between the wind and the line connecting source and sampler, construct the triangles shown in Figure B-1. The simplest solution is to apply the law of sines to the upper triangle, but that produces a factor of tan θ in the answer, which is computationally inconvenient near $\theta = 90^\circ$, reflecting the fact that the upper triangle does not exist for $\Omega = 0^\circ$.

In the foregoing figure, Ω is the wind direction (zero degrees is North) and C is the midpoint of the line $\overline{SD}$ connecting the sampler and the dust source. From the upper triangle in Figure B-1:

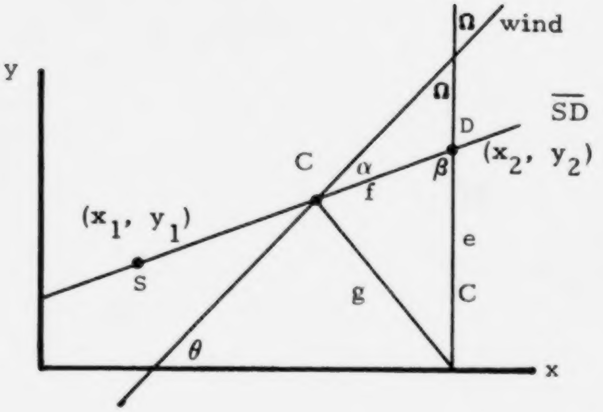
$$\begin{aligned}\alpha &= 180 - \Omega - (180 - \beta)\\ &= \beta - \Omega\end{aligned}$$

Now we must find β. Consider the lower triangle. We have,

$$g^2 = e^2 + f^2 - 2ef \cos \beta$$

or $$\beta = \text{Arccos}\left(\frac{e^2 + f^2 - g^2}{2ef}\right)$$

Where $e = y_2$



S = sampler

D = dust source

Figure B-1. Coordinate geometry for a point source.

$$f = \sqrt{\left(\frac{x_1+x_2}{2} - x_2\right)^2 + \left(\frac{y_1+y_2}{2} - y_2\right)^2} = \sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2}$$

$$g = \sqrt{\left(\frac{x_1+x_2}{2} - x_2\right)^2 + \left(\frac{y_1+y_2}{2}\right)^2} = \sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1+y_2}{2}\right)^2}$$

Substituting,

$$\beta = \text{Arccos}\ \frac{y_2^2 + \left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2 - \left(\frac{x_1-x_2}{2}\right)^2 - \left(\frac{y_1-y_2}{2}\right)^2}{2y_2\sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2}}$$

$$= \text{Arccos}\ \frac{y_2^2 + \left(\frac{y_1-y_2}{2}\right)^2 - \left(\frac{y_1+y_2}{2}\right)^2}{2y_2\sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2}}$$

$$= \text{Arccos}\ \frac{y_2^2 + \frac{1}{4}\left(y_1^2 - 2y_1y_2 + y_2^2 - y_1^2 - 2y_1y_2 - y_2^2\right)}{2y_2\sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2}}$$

$$= \text{Arccos}\ \frac{y_2^2 + \frac{1}{4}\ (-4y_1y_2)}{2y_2\sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2}}$$

$$= \text{Arccos}\ \frac{y_2-y_1}{2\sqrt{\left(\frac{x_1-x_2}{2}\right)^2 + \left(\frac{y_1-y_2}{2}\right)^2}}$$

TYPING GUIDE SHEET

Hence $\alpha = \text{Arccos} \dfrac{y_2-y_1}{2\sqrt{\left(\dfrac{x_1-x_2}{2}\right)^2 + \left(\dfrac{y_1-y_2}{2}\right)^2}} - \Omega$

To find the distance "r" of the sampler off the centerline of the plume, consider the diagram shown in Figure B-2. The distance is given by

$$r = d \sin \alpha$$

LINE SOURCE

A line source can be treated as a point source by using the midpoint of the line to calculate the following quantities: distance, the angle between the dust path to the sampler and the wind, and distance of the sampler from the plume centerline. The angle β between a line source with endpoints (x_1, y_1) and (x_2, y_2) and the wind can be calculated by considering Figure B-3.

$$\beta = 180^\circ - (90^\circ - \Omega) - (180^\circ - \theta)$$

$$= \Omega + \theta - 90^\circ$$

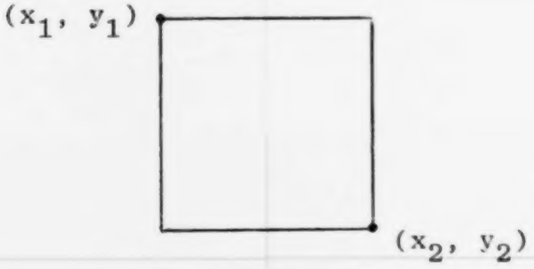
where $\theta = \text{A tan} \dfrac{y_2-y_1}{x_2-x_1}$

The angle α between a line source and the line connecting its centerpoint to the sampler can be found by use of the law of sines:

$$= \text{Arcsin} \frac{\sin \sqrt{\left(x_2 - \dfrac{x_2+x_3}{2}\right)^2 + \left(y_2 - \dfrac{y_2+y_3}{2}\right)^2}}{\sqrt{\left(x_1 - \dfrac{x_2+x_3}{2}\right)^2 + \left(y_1 - \dfrac{y_2+y_3}{2}\right)^2}}$$

AREA SOURCE

Consider a rectangle square to the axes specified as:



EPA-287 (Cin.)
(4-76)

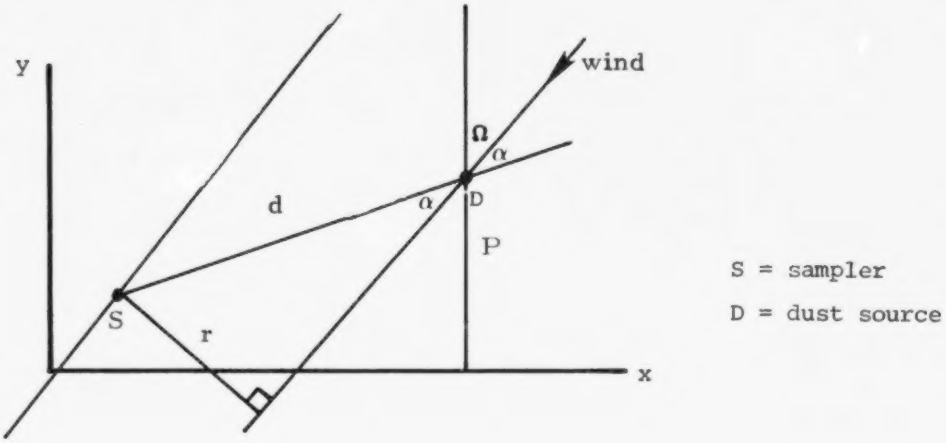


Figure B-2. Sampler distance from plume centerline.

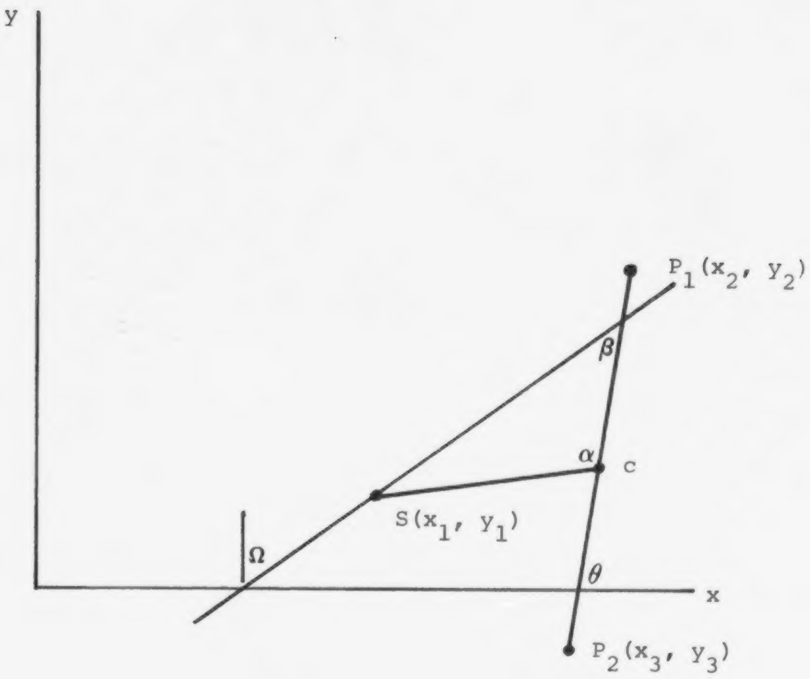
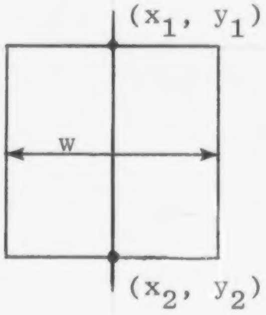


Figure B-3. Distance from line source to sampler.

Its area is $\left|(x_1 - x_2)\ (y_1 - x_2)\right|$

For a rectangle with arbitrary orientation specified as:

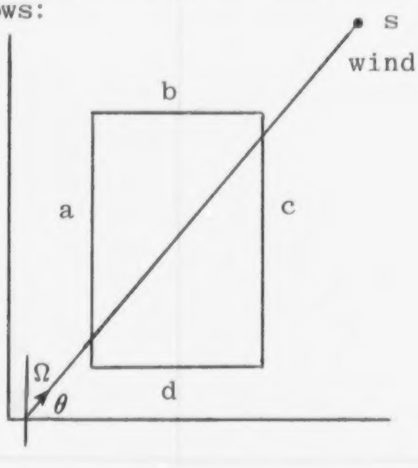


the area is $w\sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$

Let the sampler be located at (x_3, y_3). The distance from the sampler to the center of the rectangle is given by:

$$d = \sqrt{\left(\frac{x_1+x_2}{2} - x_3\right)^2 + \left(\frac{y_1+y_2}{2} - y_3\right)^2}$$

For a rectangle square to the axes described by the endpoints of a diagonal, the length of the wind's path across the area to the sampler can be computed as follows:



The wind path is: $y = \tan(90 - \Omega)(x - x_3) + y_3$

The line containing a is: $x = x_1$

The line containing b is: $y = y_1$

The line containing c is: $x = x_2$

The line containing d is: $y = y_2$

The wind path will intersect with at least two of these lines (more if it passes through a corner of the rectangle).

Intersections will occur at the following coordinates:

$$(x_1,\ \tan(90 - \Omega)(x_1 - x_3) + y_3)$$

$$\left(\frac{y_1 - y_3}{\tan(90 - \Omega)} + x_3,\ y_1\right)$$

$$(x_2,\ \tan(90 - \Omega)(x_2 - x_3) + y_3)$$

$$\left(\frac{y_2 - y_3}{\tan(90 - \Omega)} + x_3,\ y_2\right)$$

These intersection points can be tabulated and compared with the endpoints of the lines a, b, c, and d to see if the wind has passed through the rectangle.

Case 1. There are two intersection points. The wind path length is the distance between them.

Case 2. There are more than two intersection points. The wind path length is the distance between the two non-identical points.

Case 3. There are no intersection points. The path length is zero.

Case 4. The wind is at 0°, 90°, 180°, or 270°. For two of these cases, $\tan(90 - \Omega)$ cannot be calculated. The wind path can be described by one coordinate alone. It may miss the rectangle (length zero) or pass through it (length a or b).

For the case where the rectangle is skewed with respect to the axes and is specified by a center line and width, construct the diagram shown in Figure B-4.

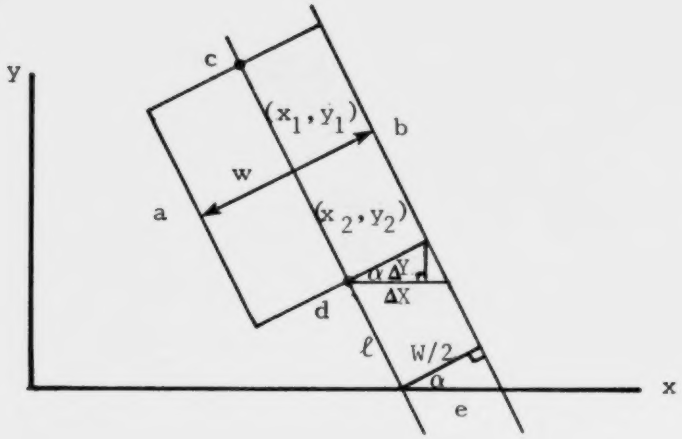


Figure B-4. Skewed area source geometry.

The centerline ℓ is given by

$$y = (x-x_1)\frac{(y_2-y_1)}{(x_2-x_1)} + y_1$$

$$= mx + b$$

where $m = \dfrac{y_2-y_1}{x_2-x_1}$ and $b = y_1 - \dfrac{x_1(y_2-x_1)}{(x_2-x_1)}$

Lines a and b are parallel to ℓ and therefore have the same slope, but their intercepts differ from b by an amount e, where:

$$e = w/2 \cos \boldsymbol{\alpha}$$

and $\text{Atan } m = 90 + \boldsymbol{\alpha}$

so $e = w/2 \cos ((\text{Atan } m) - 90)$

Now we have a $\epsilon \{y \mid y = mx + b - e\}$

and b $\epsilon \{y \mid y = mx + b + e\}$

Lines c and d are perpendicular to a and b and pass through (x_1, y_1) and (x_2, y_2) respectively. Therefore:

c $\epsilon \{y \mid y = -\frac{1}{m}(x-x_1) + y_1\}$

d $\epsilon \{y \mid y = -\frac{1}{m}(x-x_2) + y_2\}$

We can find the corner-points by their distances $\pm\Delta x$, $\pm\Delta y$ from (x_1, y_1), (x_2, y_2).

$$\Delta x = \frac{w \cos \boldsymbol{\alpha}}{2} \qquad \Delta y = \frac{w \sin \boldsymbol{\alpha}}{2}$$

Where $\boldsymbol{\alpha} = (\text{Atan } m) - 90$ as before.

By symmetry we have values for the points:

$a \cap c = (x_1 - \Delta x, y_1 - \Delta y)$

$$a \cap d = (x_2 - \Delta x,\ y_2 - \Delta y)$$

$$b \cap c = (x_1 + \Delta x,\ y_1 + \Delta y)$$

$$b \cap d = (x_1 + \Delta x,\ y_1 + \Delta y)$$

Let the wind path be given as in the previous example by:

$$y = \tan\,(90 - \Omega)\ (x - x_3) + y_3$$

The intersection of this line with the lines containing a, b, c, and d can be found, and analysis can then proceed as before.

To locate the intersection of the wind path with a, let $\theta = 90 - \Omega$ and

$$\tan\theta\ (x - x_3) + y_3 = mx + b - e$$

$$(\tan\theta - m) = b - e + x_3 \tan\theta - y_3$$

wind $\cap$ a

$$x = \frac{b + e + x_3 \tan\theta - y_3}{\tan\theta - m}$$

y can be found by substitution.

For line b,

$$\tan\theta\ (x - x_3) + y_3 = mx + b + e$$

wind $\cap$ b

$$x = \frac{b + e + x_3 \tan\theta - y_3}{\tan\theta - m}$$

For c,

$$\tan\theta\ (x - x_3) + y_3 = -\frac{1}{m}(x - x_1) + y_1$$

wind $\cap$ c

$$x = \frac{x_3 \tan\theta - y_3 + \frac{y_1}{m} + y_1}{\tan\theta + \frac{1}{m}}$$

Similarly, for d,

wind $\cap$ d

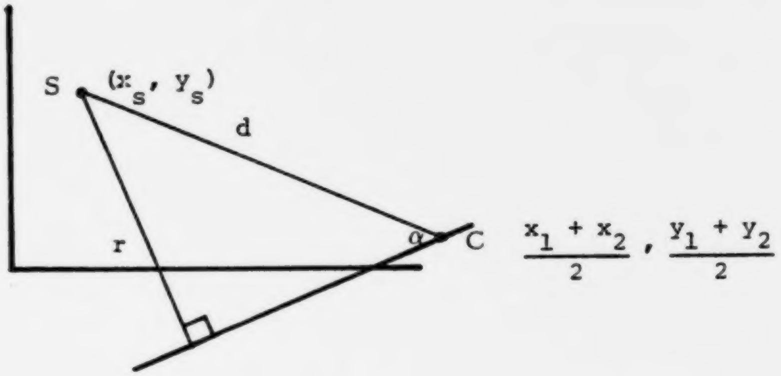
$$x = \frac{x_3 \tan\theta - y_3 + \frac{y_2}{m} + y_2}{\tan\theta + \frac{1}{m}}$$

If the wind blows due north or south, tan θ cannot be computed. In these cases, the wind path will intersect the four lines at $x = x_s$, where x_s is the x-coordinate of the sampler.

The distance from centerpoint of the rectangle to the samples is clearly:

$$d = \sqrt{\left(\frac{x_1 + x_2}{2} - x_s\right)^2 + \left(\frac{y_1 + y_2}{2}\right)^2}$$

The plume centerline will pass through the centerpoint and have slope ($90^\circ - \Omega$). Let "r" denote the distance of the sampler off plume centerline, as shown below:



Then $r = d \sin \alpha$ where

$$\alpha = A \cos \left[\frac{y_s - \frac{y_1 + y_2}{2}}{2\sqrt{\left(\frac{\frac{x_1+x_2}{2} - x_s}{2}\right)^2 + \left(\frac{\frac{y_1+y_2}{2} - y_s}{2}\right)^2}} \right] - \Omega$$

APPENDIX C

LITERATURE SURVEY

INTRODUCTION

During recent years, there has been increasing concern about the detrimental effects of pollution to the environment. A main object of the present project is to determine the levels of fugitive dust at western surface coal mines and model the relative contributions of mining operations and the on- and off-mine environment. These dust levels represent the result of three processes: emission, dispersion, and deposition. Numerous studies have already been conducted in several areas to model these processes.

The first task of this project has been to conduct a literature review to identify, collect, evaluate, and incorporate appropriate results of previous studies which are pertinent to the research effort. With regard to the importance of literature research, the following comments by the World Health Organization in Geneva seem appropriate:

(1) The first comment is that air pollution is a subject which seemed to be rather simple at first, but which has been found to be more and more complex as it has been explored. Not only is it now known that the oxidant type of pollutant which is associated with what might be called a "hydrocarbon economy" is extremely complex in nature, but it is beginning to be suspected that the reducing type of pollution -- referred to in general as sulfur dioxide -- is also very complex, a supposition which could account for the fact that concentrations which used to be thought of as quite harmless have been shown to cause considerable injury to health.

(2) The result of this complexity is that though it is fairly easy to obtain generalized information about air pollution, the cost involved in taking the step inwards towards the heart of the problem rises out of all proportion to the amount of information obtained.

(3) The preceding two statements lead naturally to the observation that a great many of the research

projects which have been instituted during the last sixty years have produced inconclusive results (a) because the design of the experiments was inadequate for the problem, or (b) because the experimental and organizational structure was deficient, owing to the fact that the funds available were quite insufficient for the task in hand.

(4) It is noticeable in studying the history of air pollution that there has been a tremendous amount of repetition of experiments, discoveries and observations. This means that the waste of effort on the research side has been enormous, but it is not at all certain that effort has been wasted on the social side. It is quite evident that the implications of air pollution to society in the spheres of health, amenity, comfort, and straight cost have never been clear to the community in the past sixty years, in spite of the efforts of control associations. Thus the continual production of scientific review articles giving a general idea of the issues involved in air pollution has rendered a very valuable service in forming in the public mind a desire to deal with the problem, a realization that it can be dealt with, and a willingness to supply the funds which are necessary to deal with it. Notwithstanding this consoling thought, however, in many cases the pooling of money and of workers could have produced experimental projects which would have reached a conclusive end-point; instead one is left with tantalizing suggestions of what might have been found if only something had been done better.

It is clear that the theoretical and applied research of others cannot be ignored. The literature cited in this report concerns:

- Estimation of the dispersion of airborn particulates as a function of meteorological variables;
- Estimation of surface wind erosion as a function of surface and meteorological parameters;
- Estimation of emissions factors for various mining activities.

Atmospheric levels of fugitive dust are dependent on three types of activities. These are surface forces which cause wind and mechanical erosion (emissions), air motion off the surface which transport the particles horizontally and vertically (dispersion), and gravitational forces which cause deposition of the particles at points downwind from the mine. The three factors -- emissions, dispersion and deposition -- must all be considered in defining fugitive dust levels. Also, particle size is a very important factor. For example, under moderate wind speeds, dust particles exceeding thirty microns in diameter may comprise a significant portion of the mass of emissions, but are an insignificant contribution to downwind air pollution concentrations because of their high deposition rate.

EMISSION MODELS

Accounting for Weather Conditions: Precipitation-Evaporation Index

The manual published by EPA (1975) is a useful guide for estimating seasonal or annual emission rates from emissions sources. However, these emission rates must be adjusted when daily climatic conditions are substituted for long-term average weather conditions. The three primary climatological variables which have a significant effect on local dust conditions are wind speed, temperature, and precipitation. Long-term emissions models use average wind speed and an average monthly index known as Thornthwaite's precipitation-evaporation index. As a substitute for this index, variables such as the fraction of days in which less than 0.01 inches of precipitation occur are sometimes used. A problem in developing an hourly model is to replace the annual precipitation-evaporation index with an hourly measurement. We give such a measurement next.

The rate of dust emissions from a surface depends on the soil moisture, which in turn depends on the precipitation and temperature. Thornthwaite (1931) developed a precipitation-evaporation index which is expressed as a relation between temperature and precipitation. For a single month, the ratio between precipitation and evaporation is defined by

$$\frac{P}{E} = 11.15 \left(\frac{P}{T - 10} \right)^{10/9}$$

where P is inches of precipitation and T is the monthly average temperature expressed in degrees Fahrenheit. Under freezing conditions, when the soil moisture is in the solid state, the P/E ratio should be independent of T. Thus, the above formula for tempertures less than 28.4°F is calculated at $T = 28.4^{\circ}$. Also, P/E ratios greater than 40 are counted as 40 because such ratios represent rain-forest conditions. The annual PE index is defined to be 120 times the average of the monthly P/E indices, i.e., PE is ten times the sum of the twelve monthly P/E indices.

Dust emission models, such as the wind erosion model defined by Woodruff and Siddoway (1965), use formulae dependent on soil moisture which are of the form

$$E = K/(PE)^2$$

TYPING GUIDE SHEET

where E represents annual emissions, K is a function of surface soil and weather conditions, and PE is the annual P-E index. A difficulty with such equations is that there are no equivalent representations for estimating dust emissions on an hourly or daily basis. The variable PE is a climatological variable, not a weather variable.

To develop an emissions model based on short-term precipitation and temperature data, consider the ratio

$$pe = \left(\frac{720}{t} \; \frac{P_t}{T - 10}\right)^{10/7} \qquad 115 \times 12$$

where P_t = inches of precipitation during t hours

$\frac{720}{t}$ = scale-up factor to equate P_t to monthly precipitation

T = average temperature ^{o}F during t hours.

Then pe is a short-term P/E ratio. The formula which can be used to estimate emissions during the eight-hour sampling periods for field measurements is

$$E = \frac{K}{pe^2} \quad \text{if } pe > 10; \; E = \frac{K}{100} \quad \text{if } pe < 10$$

The lower limit of 10 for the pe index was taken from the minimum value of Thornthwaite's PE indices for the continental United States. When pe < 10 occurs, no soil moisture is assumed.

To calculate pe, it is reasonable to use a value of t equal to the number of hours since the last period of precipitation. Thus, $1/pe^2$ will be zero during precipitation and will decrease to 0.01 as t increases.

A similar formula can be applied to the watering of roads. Suppose K gallons of water are applied to an area of X square inches. This is equivalent to 231 K/X inches of rainfall. This value should be added to P to obtain total precipitation on a road.

To a certain extent, the above definition of an hourly PE index is unsatisfactory. If emissions are calculated over each hour for a year, the calculated annual emissions will not equal those given by using an annual PE index. PEDCo, in their empirical study (1976), showed that the PE index is proportional to the percent soil moisture in the upper 4 to 6 inches of the soil. From their tables, it can be deduced that the PE index is 3.7 times the percent soil moisture.

EPA-287 (Cin.)
(4-76)

Soil moisture data has been collected for this project. Both the above hourly PE index and the value 3.7 times percent soil moisture will be used in developing dust emissions estimates.

Seasonal PE indices for each quarter are derived using the formula

$$4 \sum_{i=1}^{3} 115 \left(\frac{P_i}{T_i - 10}\right)^{10/9}$$

where P_i and T_i are monthly precipitation and temperature and the scale-up factor four is the necessary value to match an annual index. For each quarter, the emission rate is given by $E = K/PE^2$ if $PE > 10$ where K and PE depend on the mining and climatological variables for each quarter.

The above formulae apply to all mining activities except dragline activities, blasting, and coal loading and unloading. The expected activities are subsurface activities on which precipitation has no effect. We now give some specific emissions models.

Unpaved Roads

Other Research --

Much research has been done on particle deposition and particle transport under the influence of wind disturbance. The physics of particle motion under turbulence is necessary in developing estimates of particle deposition on roadways and resuspension from vehicles. Classics in the physics of dust transport under the three components of airborne suspension, saltation, and surface creep are the book by Bagnold (1954), The Physics of Blown Sand and Desert Dunes, the paper by Chepil, "Dynamics of Wind Erosion -- I. Nature of Movement of Soil by Wind," and more recently the book by Allen (1970), Physical Processes of Sedimentation. When the physics of wind turbulence due to weather variables, vehicle speed, and vehicle size are determined, formulae can be developed for the emissions rate from roadways as a function of surface properties.

The University of Washington (Pilat, et al.) developed emission rates of dust from paved and unpaved roads. Gravel roads and unpaved parking lots contributed significantly to paved road emissions due to dirt carryout of cars from under the fenders and on the tires. Roberts and Walters (1974) refer to this report in their "Estimates of the Cost and Benefits of Road Dust Control in Seattle's Industrial Valley."

Examples of previous work in the area of particle resuspension from paved roads are the field experiments by Sehin (1975). Known amounts of zinc sulfide tracers were placed on one lane of a two-lane highway. Data was then collected on the resuspension rate of the tracer for single passes of a light vehicle (car) and heavy vehicle (truck) on the by-pass lane and the tracer-laden lane of the highway for varying speeds, and weathering times (number of day after the tracer had been placed on the highway). In this study, the particle resuspension rate decreased with weathering time. However, the particle deposition rate increased with the weathering day. The explanation for this phenomenon is that the zinc sulfide particles agglomerate to form heavier particles over time. Thus, while less mass is resuspended due to the heavier mass of the particles, those particles which are resuspended have a higher deposition rate.

Data from the Sehel report could be used in developing formulae for deposition due to vehicle-caused roadway dust resuspension. Care must be used, however, in interpreting the deposition data. Because of airflow disturbance due to the use of ground deposition samplers, the redeposition of ZnS is estimated to be higher than that which would have occurred at the smoother nearby soil. The measured deposition can be used only to estimate the surface air concentration and, hence, the terminal velocity of the particles. Surface characteristics such as roughness and electrostatic properties must be included to obtain final deposition rates.

Emissions from Unpaved Roads --

When a vehicle travels over an unpaved road, the force of the wheels on the road causes pulverization of the surface material. Particles are lifted and dropped from the rolling wheels. These particles and those on the road surface are exposed to strong air currents caused by the moving vehicle.

Emissions from unpaved roads vary linearly with traffic volume. Limited field measurements indicate that vehicles produce dust from an unpaved road in proportion to the number of tires and the width of tires. Also, at least in the 30 to 50 mph category, dust emissions are roughly proportional to speed. If s denotes the percentage of silt among the loose, dry, surface dust (found by using a 200-mesh screen) then the emission factor is defined by

$$E = (0.81\ s) \left(\frac{S}{30}\right)$$

where E = emissions per vehicle mile

S = vehicle speed (mph).

This formula should be adjusted to develop a daily formula for emissions which account for precipitation, road watering, and wind erosion of the roads. Because this equation was developed in the dust bowl area of the Great Plains, zero soil moisture can be assumed. The recommended formula is:

$$E = 0.81\ s \left(\frac{S}{30}\right) \frac{100}{pe^2}$$

and

$$E = 0.81\ s \left(\frac{S}{30}\right) 1 - \frac{w}{365}$$

where the first equation is an hourly formula dependent on local temperature and precipitation conditions (see the previous section for defining pe in terms of soil moisture or in terms of precipitation and temperature). The second equation is an annual formula used by PEDCo. In the second equation, w is the number of days per year in which at least 0.01 inches precipitation occurred. The precision of the equation is assumed to be ± 10% under no surface moisture and ± 20% when the weather variable is included.

The silt content of gravel roads is approximately 12%. This figure will be used for coal haulage roads. Test results indicate that, on the average, dust emissions from unpaved roads have the following particle size characteristics:

Particle Diameter	Weight Percent
$< 2\ \mu m$	25
$2\ \mu m - 30\ \mu m$	35
$30\ \mu m - 100\ \mu m$	40

Thus, the emissions for windborne dust ($< 30\ \mu m$) are estimated to be 0.61 E. The final estimate of emissions for trucks on unpaved roads is obtained by multiplying by C_1 where C_1 is the total truck tire width to that of automobiles.

To estimate wind erosion across the road surface one can use the wind erosion equation with the following variables:

road width = 25 C_1 feet
road area/mile = 3.0 C_1 acres
vegetative cover = 0
roughness factor = 1.0 (no ridges)
C, climatic factor = 34.5 $V^3/(PE)^2$

where V^3 = wind velocity during sampling period.
L, unsheltered wind distance = 300 feet.
I, soil erodibility = primarily 70% loams and sandy clay with 30% sandy loams and clay.

The wind erosion equation then gives (see section on wind erosion)

$$E = 0.038\ C \text{ tons/acre/year}$$

$$= C_1\ (0.113\ C) \text{ tons/mile/year}$$

$$= \frac{3.90 V^3 C_1}{(PE)^2} \text{ tons/mile/year.}$$

Coal Loading/Unloading Emissions

Dust is generated at the truck loading operating by the scooping of loose material by the shovel, dumping from the shovel into the truck, and movement of trucks into position to be loaded. Several emission estimates have been made for the entire operation. Emission estimates are given in the following table.

Research Organization	Type of Material Loaded	Emission Factor
PEDCo	Lignite coal in ND	0.02 lb/ton
ERT	Coal mines in CO	0.048 lb/ton
Midwest Research Institute	Crushed rock	0.05 lb/ton
Hittman	Coal "windage loss" due to haulage	0.80 lb/ton

Hittman's estimate cannot be used because it is not known how much of the "windage loss" occurs at coal loading or what fraction remains airborne. The remaining three emission factors are in close agreement. ERT's estimate is based on the assumption that overburden removal emissions (0.048 lb/ton) are the same as coal loading emissions. PEDCo's estimate is obtained from Midwest Research Institute's estimate. Because coal has a higher moisture content than crushed rock, the value 0.05 lb/ton for rock was reduced to 0.02 lb/ton for coal. From our view, PEDCo is correct. The estimate given by ERT should have been reduced for the same reason, i.e., coal may be heavier, have higher moisture content, or have less fines than in the overburden removal emissions from which the estimate is taken. Thus, as an initial estimate, the value of 0.02 lb/ton will be used for an emissions factor for coal loading.

Coal unloading involves only the dumping of trucks with a tipple or receiver hopper for the primary crusher. Dust is generated as the material tumbles from the truck bed and strikes the ground or side of the hopper. Two different estimates of the emission rate of fugitive dust from this operation can be given. Midwest Research Institute's emissions estimate for crushed rock or gravel is equivalent to 0.04

lb./ton. This estimate is partly subjective because it was not made separately from other coal handling operations.

PEDCo used an emission factor of 0.02 lb./ton for coal-truck dumping. This value was derived by taking one half of Midwest's emission factor. This reduction was based on the larger size of the coal being handled and its moisture content.

Dragline Emissions

Overburden removal entails removal of all topsoil, subsoil, and other strata overlying the coal seam to be mined. Scrapers and bulldozers are used to remove the topsoil which is then stored to be used later for reclamation. The remaining overburden is removed by large-scale excavation equipment (we are here concerned only with western surface mining), usually draglines, which deposit the overburden in spoil banks in a trench left by the previous strip. Thus, only the initial strip produces waste overburden that must be disposed of or stored for land reclamation. The trenches are normally about 100 to 200 feet wide.

Thus, the two primary fugitive dust sources associated with overburden removal are:

- Dumping of dragline buckets or shovel full of overburden material into adjacent trenches or spoil banks.

- Operation of bulldozers and scrapers in topsoil and subsoil removal and transfer.

In this section we are concerned with dragline fugitive dust emissions.

No sampling for fugitive dust from the dragline operation has been made. PEDCo has estimated that the dragline operation at a lignite surface mine in North Dakota had an emission rate of 0.05 lb/ton of overburden removed. Engineering Research and Technology (ERT) in their Northwest Colorado report to the Bureau of Land Management proposed an emission factor equivalent to 0.048 lb/ton for topsoil removal, overburden removal, or coal removal including a correction factor for climatic conditions and control measures. These estimates suggest the preliminary emissions formula

$$E = (0.05 \text{ lb/ton}) (\text{overburden tons moved during hour})$$

to estimate dragline emissions during each hour of operation. Because dragline excavation is a subsurface operation, no correction for climate is necessary.

TYPING GUIDE SHEET

Scraper Activity -- Topsoil Removal and Replacement

Scraper activity can be measured by the number of scraper-hours. A simple emissions model is defined by

$$E = a\ S_c$$

where S_c is the number of scraper-hours in a region. As in coal haulage, dust emissions occur at the loading and dumping points and during the transportation between scraping and dumping. Because most of the dust occurs at the surface during transportation, the soil moisture variable $100/pe^2$ is included as a factor in the emissions estimate. PEDCo has estimated that the factor a is 16 lbs per hour operation of a scraper. Because a PE index was not used in developing this equation, one could use the estimate

$$E = 16\ S_c \left(\frac{PE}{pe}\right)^2$$

where PE is the annual PE index and pe is an hourly estimate. Presumably, the annual weather factor $(1 - w/365)$ is not applicable because topsoil removal or replacement does not occur under inclimate conditions.

Agricultural Tilling -- Land Reclamation

Field testing of dust emissions from agricultural tilling was conducted by PEDCo in Morton County and Wallace County, Kansas. From this, they derived an equation for tilling which may be used for activities such as grading, which cut, granulate, and invert the soil. This is given by

$$E = \frac{\alpha s}{(PE/50)^2} \times \frac{S}{5.5}$$

where E = emission factor, lbs/acre
s = percent silt content of surface soil
PE = Thornthwaite's (1931) precipitation-evaporation index
α = parameter which is 1.4 (PEDCo 1976)
S = implement speed (mph).

With $\alpha = 1.4$, about 80% of the emissions lie in the 30 micron-airborne fugitive dust category. Test results indicated that, on the average, dust emissions from agricultural tilling have the following particle size characteristics:

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

Particle Diameter	Weight Percent
2 μm	35
2 μm - 30 μm	45
30 μm	20

Data from which this equation is derived are presented in Tables C-1 and C-2. From these tables, we estimate that the percent silt content is 26% for sandy loam, 32% for loam, and 48% for silt loam soils.

PEDCo estimates the precision of the agricultural tilling emissions formula to be 15%.

Blasting

Drilling and blasting are done to fracture hard, consolidated material so it can be removed easily by excavating equipment. The blastholes are drilled to the depth to which the coal or rock layer is to be broken. If the seam depth is great, shelves of 30 to 50 feet deep are often used. Typical blasting patterns range from 20 feet by 20 feet to 50 feet by 100 feet.

Two types of emissions models can be used for blasting. The more complex model would have emissions dependent on the type of material, the amount of explosives, the depth of the bench below the highwall, and the spacing of the explosives. Such a model can be derived theoretically using the physical laws of particle acceleration under blasting. Such a model is unduly complex for this project.

A simple model is given by

$$E = \frac{a\ Bh}{f} \text{ per blast}$$

where a is an unknown parameter, B is the annual coal production, h is the total pounds (or sticks) of explosives used in the blast, and f is the total pounds (or sticks) of explosives used per year. This formula assumes the total annual emissions due to blasting is proportional to the material (coal) excavated, but also weighs each blast according to the size of the blast.

PEDCo estimated emissions from daily blasting at a large open pit copper mine to be 200 lb. of suspended material per blast, or about 0.001 lb/ton of ore. This estimate is only an order of magnitude value based on visual observation.

EPA-287 (Cin.)
(4-76)

TABLE C-1. SOIL PROPERTIES (AGRICULTURAL TILLING)*

			Moisture (%)		Texture, 0-4 in. depth (Λ by weight)[a/]					
Run	Site	Soil type	0-4 in. depth	4-6 in. depth	Medium coarse sand (2000-250 m)	Fine sand (250-105 m)	Very fine sand (105-50 m)	Coarse silt (50-20 m)	Fine silt (20-2 m)	Clay (2 m)
5	A1	Sandy loam	10.5	10.7	2	35	17	14	12	20
6	A1	Sandy loam	-	-	2	35	17	14	12	20
7	A1	Sandy loam	-	-	2	35	17	14	12	20
9	A2	Loam	11.0	-	8	10	22	16	16	28
11	A3	Silt loam	15.9	19.7	1	1	20	30	18	30
12	A3	Silt loam	13.4	17.5	1	1	21	30	19	28
14	A4	Silt loam	12.3	18.5	5	3	18	27	19	28

a/ Determined by Buoyocous hydrometer method.

* Reprinted from EPA-450/3-74-037, "Development of Emissions Factors for Fugitive Dust Sources," p. 61.

TABLE C-2. ESTIMATED VS. ACTUAL EMISSIONS* (AGRICULTURAL TILLING)

Run	Site	Implement Speed (mph)	Soil Properties[a] Percent Silt	Soil Properties[a] Moisture (% by weight)	Equivalent PE[b]	Emission Factor (lb/acre) Estimated	Emission Factor (lb/acre) Actual	Percent Difference
5	A1	5.5	26	10.5	40	57	56	2
6	A1	5.5	26	10.5	40	57	52	9
7	A1	5.5	26	10.5	40	57	60	-5
9	A2	4	32	11.0	41	49	42	16
11	A3	6.5	48	15.9	59	56	64	-12
12	A3	7	49	13.4	50	87	85	2
14	A4	5	46	12.3	46	70	78	-10

a/ 0-4 in. depth.
b/ Precipitation-evaporation index, adjusted to soil moisture.

*Reprinted from EPA-450/3-74-037, "Development of Emissions Factors for Fugitive Dust Sources," p. 68.

Wind Erosion

The wind erosion equation was developed by the late Dr. W.S. Chepil. It is the result of nearly thirty years of research to determine the primary variables or factors that influence erosion of soil by wind. The equation is designed to determine (1) if a field is adequately protected from wind erosion, and (2) the different field conditions of cloddiness, roughness, vegetative cover, sheltering from wind barriers, or width and orientation of field required to reduce potential soil loss to a tolerable amount under different climates. The wind erosion equation developed by Chepil is presented in Woodruff (1965) together with some applications.

The wind erodibility of land surfaces is governed by eleven primary variables. A brief description of each follows.

Soil Erodibility Index --

This is the potential soil loss in tons per acre per annum from a wide, unsheltered, isolated field with a bare, smooth, noncrusted surface. Its value, related to soil cloddiness, decreases as the percentage of soil fractions greater than 0.84 mm in diameter decreases. It can be determined by standard dry sieving procedures. Clearly, this index should also consider the density of the material.

Knoll Erodibility Index --

This factor computes erodibility for windward slopes less than 500 feet long. It is expressed in terms of percent slope. For slopes longer than 500 feet, the index is about the same as level and is therefore 100%.

Surface Crust Stability --

This is an erodibility factor dependent on the extent of surface crusting. According to Woodruff, this factor can be ignored. However, at a mine in North Dakota, the clay in the spoil forms a crust after the rain. This crusting appears to give complete protection from wind erosion provided there is no abrasion of the crusted surface.

Soil Ridge Roughness --

This is a measure of soil surface roughness other than cloddiness. It is the natural or artificial roughness of the soil surface in the form of ridges or small undulations. It can be determined from a linear measure of surface roughness.

Soil Surface Moisture --

The rate of soil movement varies approximately inversely as the square of effective surface soil moisture. When soil moisture is unavailable, this variable can be assumed to be proportional to the Thornthwaite P-E index.

Distance Across Field --

This is the total distance across a field along the prevailing wind direction. The rate of soil flow is zero on the windward edge, and increases to the maximum that a wind of a particular velocity can sustain as the distance from the edge is increased. Thus, soil erosion is minimized by having narrow strips of unprotected field perpendicular to the prevailing wind.

Sheltered Distance --

This is the distance that a prevailing wind erosion direction is sheltered by a barrier. A general formula is obtained by multiplying the height of the barrier by ten.

Quantity, Kind, and Orientation of Vegetative Cover --

These three factors can be combined into a single factor which measures the effect of vegetative cover on soil erodibility.

The modified wind erosion equation defined by Woodruff is as follows:

$$E = a\ I\ KCL'V'$$

where a = portion of emissions which are suspended particulates
I = soil erodibility
K = surface roughness factor
C = climatic factor
L' = unsheltered field width factor
V' = vegetative cover factor

The climatic factor C is defined by

$$C = \frac{34.5 \times 100\ v^3}{(PE)^2}$$

where v is the wind velocity. (Average values of C have been developed by the USDA for different parts of the country.) The value of K can vary between 0.5 and 1.0, depending on the surface roughness features. For off-road exposed areas we shall use the value K = 0.5. Values of a and I are given in the following table:

Surface, Soil Type	a	I, Ton/Acre/Year
Rocky, gravelly	0.025	38
Sandy	0.010	134
Fine	0.040	52
Clay loam	0.025	47

For off-road areas, the exposed mining areas can be considered to be of sufficient width so that L' = 1.0

By substituting the appropriate values above, an emission factor E can be developed for each mine during each sampling period. This factor gives tons/acre/year.

PARTICLE SIZE AND DEPOSITION RATES

Particle Size Distribution of Fugitive Dust

Significant sources of atmospheric dust arise from the mechanical disturbance of granular material exposed to the air. Dust generated from these open sources is termed "fugitive" because it is not discharged to the atmosphere in a confined flow stream. The dust generation process is caused by two basic physical phenomena:

(1) Pulverization and abrasion of surface materials by the application of mechanical forces.

(2) Entrainment of dust particles by the action of turbulent air currents. Airborne dust may also be generated independently by wind erosion of an exposed surface if the wind speed exceeds 12 mph.

The impact of fugitive dust emissions depends on the quantity and drift of the particles injected into the atmosphere. Theoretical drift distances, as a function of particle diameter and mean wind speed, have been computed for unpaved road emissions. For a typical wind speed of 10 mph, particles larger than 100 microns are likely to settle out within 20 to 30 feet from the edge of the road. Particles that are 30 to 100 microns undergo impeded settling. These particles settle within a few hundred feet of the road, depending upon the extent of atmospheric turbulence. Based on these results, particle emissions smaller than 30 microns are generally recognized as emissions which may remain indefinitely suspended and hence are airborne.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

The size of particulates is important in assessing air pollution impact. Particulates are minute solid particles or liquid droplets ranging in size from 0.005 to about 500 microns. (A human hair, by comparison, has a thickness of about 100 microns.) According to Fennelly (1976), natural dust, although it comprises almost half of the total mass of particulate matter injected into the atmosphere, has a relatively small impact. Dust particles are generally larger than 10 microns and are fairly dense, so they quickly settle out of the atmosphere.

According to Fennelly, it is very difficult to create dust particles smaller than a few microns in diameter by either pulverizing or grinding larger particles. The limiting factor is the large amount of energy required to provide the additional surface energy that accompanies an increase in the number of smaller particles. Thus, particles smaller than 5 microns (Fennelly uses the more vague limit "smaller than a few microns") can be assumed to be the result of high-energy systems such as combustion engines and furnaces.

Because deposition rates depend on particle size, it is important to have an estimate of particle size distribution. Recent experiments have shown that aerosol mass is bimodal, with modes depending on the emissions sources in the area of a receptor. Because airborne dust lies in the upper tail of particle sizes, the distribution of size can be expected to change with distance from a source. The percentage of mass comprised by the larger particles will decrease with distance because of the high deposition rate for large particles.

Lundgren and Paulus (1975) showed that fugitive dust emissions in a rural area have a bimodal mass distribution with respect to particle diameter. When plotted on lognormal paper, two distinct and different slopes were found. One lognormal curve lies between 0 and 5 microns. The other lies between 5 and 100 microns. Thus, as an approximation for dust particles between 5 and 100 microns, we can assume a lognormal distribution whose mean and standard deviation are

$$\ell\eta M = \frac{\ell\eta 5 + 100}{2} \approx \ell\eta 22$$

$$\ell\eta\sigma_g = \frac{\ell\eta 100 - \ell\eta 5}{4} \approx \ell\eta\ 2.1$$

which give a mass median diameter of 22 microns and a geometric standard deviation of $\sigma_g = 2.1$. These values will be used in assessing theoretical deposition rates for dust particles collected in the largest filter for sizes exceeding 7 microns.

As a rough check for this distribution, consider the fraction of particulates less than 30 microns. The normalized standard deviate is

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

$$\frac{\ell\eta 30 - \ell\eta 22}{\ell\eta 2.1} = 0.42$$

The normal distribution estimate of the fraction of the total mass of particles less than 30 microns is 0.66. A report by PEDCo (1976) estimates this value to be 0.60.

The five particle sizing heads for the Hi-Vol samplers used in the field experiments would give approximately the following distribution if these assumptions are correct:

Sizing Interval (Microns)	Fraction of Mass Attributed to Dust
0.0 to 1.1	--
1.1 to 2.0	--
2.0 to 3.3	0.005
3.3 to 7.7	0.074
7.7	0.921

Particles collected in the first two filters are attributable to gaseous and fine particles from combustion sources.

In fact, the observed distributions of particle masses were quite different. The distributions varied sharply from observation to observation. At times, the largest fraction of dust lay in the smallest size category. Compared with the extremely skewed distributions tabulated above, the observed distributions look rather flat. This finding demonstrates the complexities of deposition which undermine the application of models derived in one setting to another setting.

Deposition Rate of Large or Heavy Particulates

The earth's gravitational field has a major effect on the dispersion and deposition of atmospheric particulate matter. The rate of descent of a particle depends on a balance between the aerodynamic drag force and the gravitational force exerted by the earth. Neglecting the effect of slip flow, this balance may be expressed for a smooth spherical particle by the equation

$$\eta V_g C_D = \frac{8}{3} r g \rho \qquad (C.1)$$

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

where η = atmospheric density

V_g = fall velocity

C_D = drag coefficient

r = particle radius

g = gravitational acceleration = 9.80 m/sec^2

ρ = particle density.

Using a relation $C_D = 24/Re$ where $Re = 2\eta V_g r/\mu$ is the Reynold's number, equation (C.1) reduces to Stokes' equation

$$V_g = 2\,r^2 g\rho/9\mu \qquad \text{(C.2)}$$

where μ is the atmospheric dynamic viscosity.

Equation (C.2) must be adjusted for shape and particle size. The effect of shape upon fall velocities is dependent on the definition of particle radius. If the maximum radius is used, the effect of shape, on the average, reduces (C.2) to two-thirds. However, if an average radius is used, equation (C.2) is approximately correct. That value of d such that $r = d/2$ gives the correct value in (C.2) is known as Stokes' diameter.

The effect of slip flow is expressed by multiplying the fall velocity by a slip correction factor

$$1 + \frac{\lambda}{r}\left[1.26 + 0.4 \exp\ -\left(\frac{1.1\ r}{\lambda}\right)\right]$$

where λ is the mean free path of air molecules and depends primarily on altitude. Thus, for large particles, the slip correction factor is negligible.

At 90°F, the viscosity of air is 0.0175 centipoise ("International critical tables"). The acceleration due to gravity is 980.665 cm/sec^2. For these values, the fall velocity computation for a particle with density 2.5 g/cm^3 and a radius of 10 microns is 3.11 cm/sec. Airborne fugitive dust is regarded as having particle diameter in the 0 to 30 micron range. For this range, equation (C.2) is seen to be adequate.

Equation (C.2) is inadequate for small particles because of two major factors. One is that small particles are affected by Brownian motion in a way similar to molecules. Another factor is the retention capacity of small particles at the ground. If the roughness elements on a surface are of a form providing good impaction efficiency and have a good retaining quality (as a result of stickiness, wetness or

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

hairyness) the surface may act as a perfect sink with the effective deposition velocity equal to or greater than that for momentum. Much research has been conducted to measure deposition velocity as a function of type of particle and surface. However, for dispersion modeling, this research need not be considered because the deposition velocity is so slow that the air concentration of small particles is insignificant at any distance in which the source strength has been depleted a significant amount due to deposition of small particles. Also, the fraction of dust particles which fall into the small particle category is minor, if not zero.

Thus, to calculate the deposition rate of dust particles of a given diameter d, we recommend the formula (C.2) which is equivalent to

$$v_g = \frac{d^2 \times (0.0311) \times (0.0175)}{4 \times \mu_T} \qquad (C.3)$$

where μ_T is the viscosity of air at temperature T in centipoise, 0.0175 is the viscosity of air at 90°F, $d^2/4$ is the squared particle radius, 3.11 is the value of v_g at radius 10 μm and temperature 90°F, and 2.5 g/cm^3 is the approximate density of the particles.

To incorporate deposition into the dispersion model one can use the source depletion model defined by Van der Hoven in Meteorology and Atomic Energy, 1968.

Define w(x,y) to be the surface deposition rate at (x,y) and Q(x) be the residual source strength at x meters downwind from the source. Define X(x,y,o) to be the air concentration of particles at the surface. Then the following equations are assumed to hold:

$$X(x,y,o) = Q(x)S(x,y,o) \qquad (C.4)$$

where S(x,y,o) is the air concentration under no deposition when the source strength is one unit;

$$w(x,y) = v_g X(x,y,o) \qquad (C.5)$$

where the deposition rate is the rate of fall of particles at the surface multiplied by the concentration at the surface; and

$$\frac{\partial Q(x)}{\partial X} = -\int_{-\infty}^{\infty} w(x,y)\,d\,y \qquad (C.6)$$

that is, the change in source strength at distance x is the negative of the crosswind deposition rate at distance x.

TYPING GUIDE SHEET

Equation (C.4) is incorrect because the "strength" of particles due to deposition at distance x does not change at the source, but at the distance x.

When the Gaussian plume model is used, the ratio of the depleted source to the original source can be shown to be given by

$$\frac{Q(x)}{Q(o)} = \exp\left[-\left(\frac{2}{\pi}\right)^{1/2} \frac{v_g}{\bar{u}\,\sigma_z} \int_0^x \exp\left(-\frac{h^2}{2\sigma_z^{\,2}}\right) dx\right] \tag{C.7}$$

where h = source height

σ_z = vertical dispersion coefficient

Q_o = original source strength

and $\bar{u}$ = average wind speed

Taking a simple power-law growth of σ_z with distance, i.e.,

$$\sigma_z \propto X^q$$

equation (C.7) may be integrated to give for a ground level source ($h = 0$)

$$Q(x) = Q(o) \exp\left[-\frac{2^{1/2} v_g x}{\pi^{1/2}(1-q)u\sigma_z}\right] \tag{C.8}$$

Using empirical relations suggested by Pasquill and equation (C.8), charts defining $Q(x)/Q(o)$ have been given (see Meteorology and Atomic Energy 1968, p. 204) for each stability class.

Washout in Rain

When a raindrop falls, it sweeps out a volume of air. When this volume of air separates to allow the raindrop to pass, the particles tend to follow the air. However, such physical phenomena as inertia, electrical attraction, and molecular diffusion cause a fraction of the particles to cross the air streamlines and collide with the raindrop. This fraction of the particles is known as the collision efficiency of the raindrop. Of this fraction, only a fraction, known as the retention efficiency, will be retained. The product of the collision and retention efficiencies is the collection efficiency.

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

The modeling of rain washout can be very complicated because such factors as droplet size, speed, number as well as the amount of precipitation preceeding the raindrop and the area covered by the rain must be considered. The washout coefficients for rain which we will consider are those developed by Chamberlain (1966). These coefficients can also be found in Pasquill (1974). They are dependent on rainfall rate and the fall velocity of the particles. For a value of $v_g = 0.5$ cm/sec, the washout rate is defined by a parameter Λ where

$$\Lambda = 2 \times 10^{-4} R$$

R = rate of rainfall in mm/hr.

Because Λ is approximately proportional to R, the washout due to rain can be modeled without knowing R, provided the total amounts of rainfall is known. Using a rate of 2 mm/hour, Λ is given by 4×10^{-4}. Pasquill gives the formula

$$Q_1(x) = Q_1(o) \exp \frac{-\Lambda x}{\bar{u}}$$

where $Q_1(x)$ is the reduced source strength due to rain washout and $Q_1(o)$ is the original source strength. Note that $Q_1(o)$ under rainfall conditions is less than $Q_1(o)$ under no precipitation because of dust control caused by watering of the surface. The final reduced source strength is the product of $Q_1(x)$ and the ratio $Q(x)/Q(o)$ due to deposition. Apparently, snow has a washout rate about equal to that of rainfall (see Meteorology and Atomic Energy, 1968).

DISPERSION MODELS

General Theory

Dispersion models give estimates of the contribution to air pollution concentration levels at receptor points downwind from an area, line, or point emissions source. An abundant literature exists on dispersion models. General books on dispersion include Pasquill (1974), Stern (1968), and Turner (1970). Specific models are given in Wang and Rote (1975) and the EPA report "User's Guide for the Climatological Dispersion Model," (1973). In this section we give a general description of dispersion models. A description of the Climatological Dispersion Model used for this project is given in the following subsection.

Suppose a mass of E emissions of particles or gases are airborne from a source at a location (0,0,h) where (0,0) is a point on the earth's surface and h is the vertical height of the source. Assume that the following conditions hold:

- The emissions rate E is constant over time;

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

- No emissions disappear through any process such as deposition, rainfall washout, or chemical reactions;
- The weather conditions remain constant over time;
- The wind speed u is constant at all verticle heights in which the emissions can be found.

Then, the total mass of emissions in the atmosphere between the vertical planes x and x + dx perpendicular to the wind direction, where x is a distance downwind from the source, is given by

$$\text{Crosswind integrated mass} = \frac{E}{u}\,dx \qquad (C.9)$$

This very simple equation does not define the density of airborne emissions at a point (x,y,z) per unit volume where y is a crosswind distance and z is a vertical height. However, under the assumptions above, this density must be of the form

$$\text{concentration} = f(x,y,z)\,\frac{E}{u} \qquad (C.10)$$

where $\iint f(x,y,z)\,dy\,dz = 1.$

One of the simplest types of dispersion models is the box model. Assume that at a downwind distance x, all of the airborne emissions are bounded between the crosswind distances $-y_1$ and y_2 and the vertical heights 0 and L. Assume further that the concentration is constant within these bounds. Then the box model is defined by

$$\text{concentration} = \frac{1}{y_1+y_2}\;\frac{1}{L}\;\frac{E}{u} \qquad (C.11)$$

for all points $-y_1 \leq y \leq y_2$ and $0 \leq z \leq L$. The values of y_1, y_2, and L may depend on x.

Many dispersion models use the box model for values of x which are sufficiently large. The value of L is known as the "mixing height" which is constant (to be discussed later). The assumption of homogeneity in the crosswind direction would be violated if the wind direction were constant. However, when several wind directions are averaged together in a dispersion model, errors created by the assumption of crosswind homogeneity have an average zero value. In the climatological dispersion model, $y_1 = y_2$ are crosswind distances on a sector of 22.5 degrees width along the downwind direction.

While all dispersion functions are approximately of the form in equation (C.11), more sophisticated models make adjustments for variable wind speeds as a function of height, terrain, and wind

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

turbulence. Even in the simplest dispersion models other than the box model, the function f depends on climatological variables such as "wind stability class" (Pasquill 1974). A model which is often used for moderate downwind distances x is given for fixed x by

$$f(x,y,z) = f_1(y)f_2(z) \qquad (C.12)$$

where

$$f_1(y) = \frac{1}{\sqrt{\partial \pi \sigma_y}} \exp\left(\frac{-z^2}{2\sigma_z^2}\right) \qquad (C.13)$$

and $f_2(z)$ depends on a function of the form

$$g_2(z) = \frac{1}{\sqrt{\partial \pi \sigma_y}} \exp\left(\frac{-z^2}{2\sigma_z^2}\right) \qquad (C.14)$$

The parameters σ_y and σ_z are called the horizontal and vertical dispersion coefficients. These parameters depend on x and on variables describing wind motion.

In defining the vertical dispersion $f_Z(z)$, $g_Z(z)$ must be translated to $g_Z(z - H)$ where H is the height of the center of the plume at distance x. The parameter H is also the height at which the highest concentration occurs at a given distance x. This parameter depends not only on the source height h, but also on a physical phenomenon known as plume rise. Plume rise occurs because of a temperature gradient between the emissions and the ambient air. Also, for large particles, gravitational settling must be accounted for in the vertical dispersion function.

Until now, we have ignored the boundary conditions on the atmospheric concentration imposed by the earth's surface. There are at least two assumptions which can be made concerning these boundary conditions:

Assumption 1

Fine particles are randomly diffused and are reflected at the earth's surface to the air. Then

$$f_2(z) = g_2(z - H) + g_2(-z - H) \qquad (C.15)$$

where -z is the virtual image of z. (See Figure C-1.)

EPA-287 (Cin.)
(4-76)

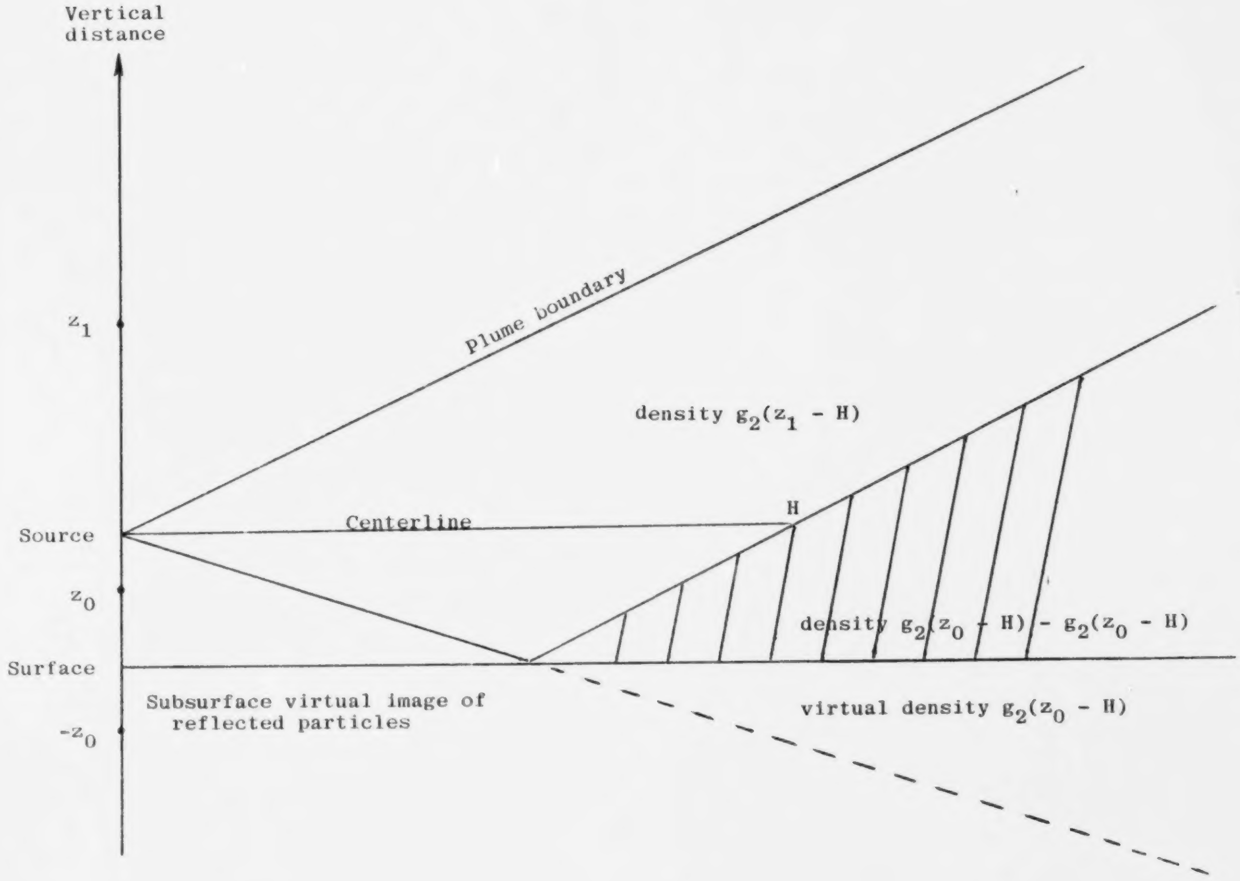

Vertical distance
z_1
Source
z_0
Surface
$-z_0$
Plume boundary
Centerline
H
density $g_2(z_1 - H)$
density $g_2(z_0 - H) - g_2(z_0 - H)$
virtual density $g_2(z_0 - H)$
Subsurface virtual image of reflected particles

Figure C-1. Fine particles are reflected.

TYPING GUIDE SHEET

Assumption 2

Heavy particles fall to the ground at a terminal velocity v. At the earth's surface, these particles are deposited. Then

$$f_2(z) = g_2(z - H) \qquad (C.16)$$

where the centerpoint H includes the terminal velocity component in the plume rise formula. (See Figure C-2.)

Assumption 2 does not adequately define deposition. If the centerline is proportional to x and the dispersion parameter σ_z is proportional to x, then the fraction of the plume above the earth's surface remains constant independent of x. In other words, the crosswind integrated concentration above the surface is constant independent of x. By definition, this implies no deposition is occurring. A third means of describing deposition is given by the formula

$$\text{concentration} = f_1(y) f_2(z) \frac{E}{u} (1 - D(x)) \qquad (C.17)$$

where $f_2(z)$ is given by equation (C.15 and D(x) is the fraction of E deposited per unit time between the source and the crosswind plume. Equation (C.16) can be used together with either the Box model (C.11) or the reflected Gaussian model defined by (C.13), (C.14), and (C.15).

EPA-287 (Cin.)
(4-76)

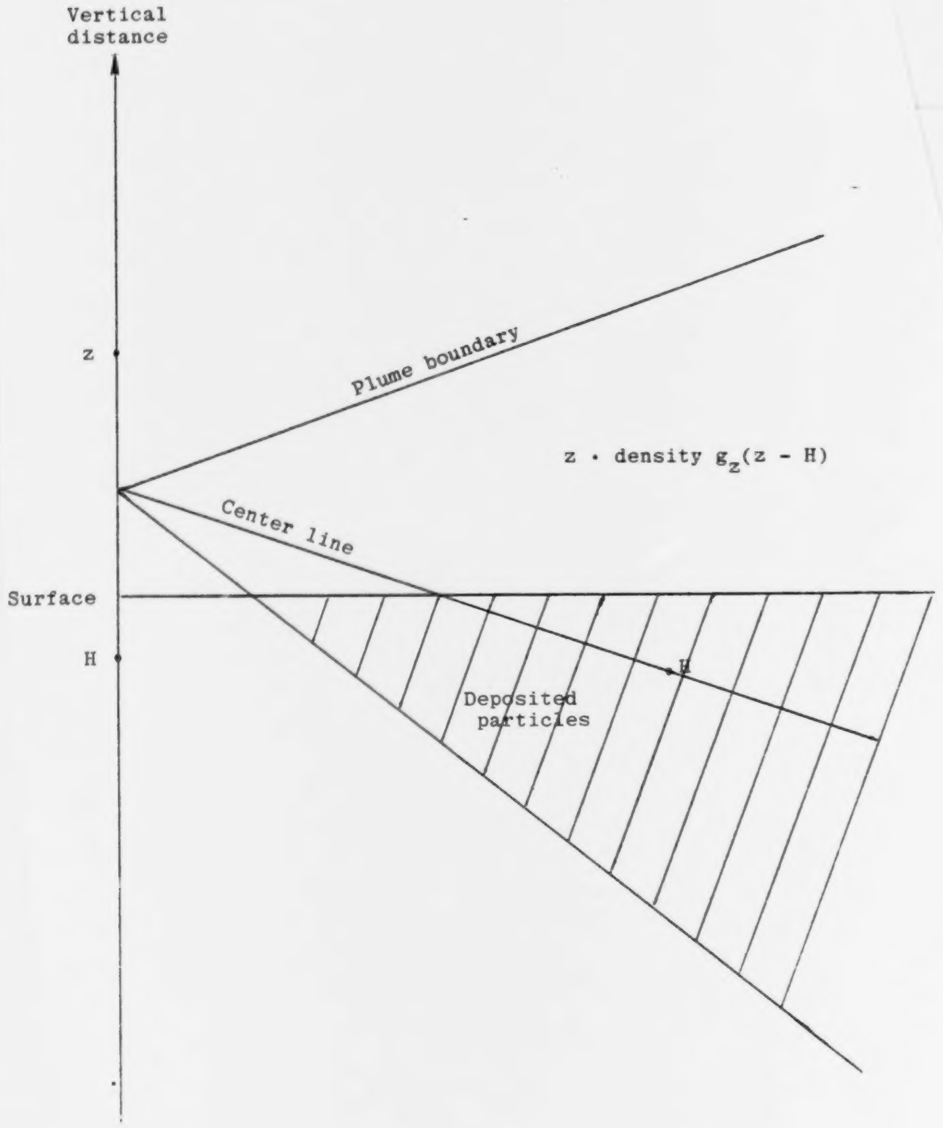


Figure C-2. Tilted plume hypothesis.

TYPING GUIDE SHEET

APPENDIX D

FIELD DATA

The following conventions apply to the field data tables:

TSP Levels TSP

-10 = missing value

Weather Data Wind Speed

-2 = wind direction variable
-3 = wind calm

Precipitation

-2 = snow

Soil Moisture

-1 = missing value

Activity Levels

Activity levels were recorded in the following units:

Dragline (DRAG), scraper (SCRA), grading (GRAD), drilling (ODRL, CDRL) in operating minutes per hour,

Blasting (BLAS) in holes,

Vehicles on public roads (PUBL) in vehicles per hour,

Loading (LOAD) and unloading (UNLD) in English tons,

Haulage (HAUL) and water trucks (WATR) in trips,

Vehicles on haul road (VEHI) in vehicle-miles per hour.

TSP size ranges are:

1 = 0 - 1.1 microns
2 = 1.1 - 2.0 microns

EPA-287 (Cin.)
(4-76)

3 = 2.0 - 3.3 microns
4 = 3.3 - 7.0 microns
5 = 7.0 + microns

The four-letter activity codes fall in the ACTIVC columns. Measurement values are recorded in the QUANT columns. The AREAC(ODE) and SEG(MENT) columns refer to aerial photographs which are not included. See Appendix A for mine maps. There are nine sets of these columns for every mine, visit, and hour.

Visits (trips) are numbered in chronological order for each mine.

							TSP (µg/ m^{-3}) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
1	1	1	1	24	20	10	22	24	20	35	54	25	5	40	570
				25	11	0	35	140	75	116	131	25	13	0	120
					13	45	24	42	17	26	29	25	18	0	255
				26	0	15	12	22	24	19	18	26	7	30	435
					8	0	14	29	27	46	30	26	12	45	285
					17	0	17	21	28	38	35	26	23	30	390
					23	45	30	10	13	23	29	27	8	40	535
		2	2	24	19	30	5	34	6	18	16	25	9	30	840
				25	9	40	27	29	23	46	39	25	14	45	325
					15	0	31	28	21	24	16	25	19	45	285
					23	10	14	32	22	31	23	26	5	40	390
				26	7	35	-10	30	23	27	28	26	12	55	320
					16	20	14	13	19	27	32	26	22	50	390
					23	35	39	20	16	17	17	27	7	20	465
				27	9	35	32	14	16	13	19	27	21	15	470
		3	3	25	0	20	23	22	21	34	34	25	7	55	455
					8	25	23	24	17	31	28	25	16	0	475
				26	1	0	14	24	20	20	2	26	8	30	450
					8	45	6	15	8	34	7	26	17	15	550
					17	45	20	40	27	44	35	26	24	0	255
				27	0	15	23	22	13	23	28	27	9	50	575
		4	4	25	7	30	33	25	21	29	-10	25	12	0	270
					17	0	24	29	24	34	26	25	21	30	270
				26	1	45	13	26	20	24	23	26	8	0	415
					9	10	10	22	8	22	21	26	16	10	420
1	2	1	1	21	10	10	2	67	199	26	10	21	15	20	310
					15	45	24	0	14	0	15	21	22	50	425
					23	15	0	27	0	45	0	22	6	45	450
				22	7	15	0	12	8	19	24	22	14	50	455
					15	10	44	59	65	13	29	22	23	5	475
					23	30	19	29	126	48	29	23	6	25	415
				23	7	20	0	45	62	52	141	23	15	30	490
					15	45	3	16	65	21	40	23	22	35	410
		2	2	21	11	45	458	62	114	120	27	21	16	0	255
					16	20	0	10	17	26	46	21	20	35	255
					23	55	0	48	3	24	23	22	7	30	455
				22	7	50	29	14	5	7	30	22	15	30	460
					15	45	5	0	52	49	229	22	20	45	300
				23	0	0	7	31	31	19	45	23	7	25	445
					7	45	33	54	51	13	137	23	16	0	495
					16	15	0	81	56	50	53	23	23	0	405

							TSP ($\mu g/m^{-3}$) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
1	2	3	3	21	12	45	443	38	11	53	19	21	16	45	240
					17	10	0	20	25	27	11	22	0	20	430
				22	0	45	57	67	40	15	10	22	2	30	105
					8	35	8	31	15	25	68	22	16	15	470
					16	30	0	33	35	32	43	23	0	25	475
				23	0	45	0	37	50	61	26	23	8	0	435
					8	45	11	13	19	171	68	23	16	40	475
					16	50	0	135	44	69	131	23	23	40	390
1	3	1	2	19	1	15	22	20	-10	16	16	19	8	35	440
					8	55	164	56	59	7	125	19	16	0	425
					16	20	327	58	76	111	206	20	0	5	465
				20	0	30	21	57	54	65	80	20	8	25	475
					8	50	10	12	16	18	13	20	16	5	475
					16	15	29	12	6	2	4	21	0	10	475
				21	0	30	68	41	0	1	7	21	8	25	475
					8	40	34	2	1	28	12	21	14	40	360
					16	5	31	0	0	4	3	22	0	10	475
		2	3	19	3	0	458	33	22	20	26	19	7	30	420
					7	50	582	105	263	53	597	19	15	15	495
					15	35	383	93	208	279	551	19	23	5	450
					23	30	72	55	55	94	123	20	7	15	465
				20	7	35	48	64	29	50	75	20	15	10	465
					15	30	32	16	10	4	18	20	23	10	440
					23	35	6	7	6	13	1	21	7	25	470
				21	7	45	16	16	25	16	33	21	15	0	435
					15	20	35	1	0	0	19	21	23	15	475
		3	4	19	0	45	27	7	11	22	27	19	8	0	435
					8	20	181	57	56	101	136	19	15	40	440
					15	55	327	42	57	84	139	19	19	55	240
				20	0	0	8	29	35	47	37	20	7	50	470
					8	15	85	5	8	23	29	20	15	35	450
					15	50	41	0	0	7	27	20	19	50	240
				21	0	0	20	0	-10	3	5	21	7	55	475
					8	15	28	10	12	1	9	21	15	30	435
					15	45	24	0	9	3	0	21	23	35	470
		4	1	19	17	10	420	67	86	118	172	20	0	35	445
				20	1	0	97	42	43	67	81	20	8	55	475
					9	20	0	17	9	0	25	20	16	25	425
					16	45	39	20	18	9	10	21	0	35	470
				21	0	55	100	12	9	12	6	21	8	50	475
					9	5	33	16	7	21	43	21	16	15	430
					16	25	26	19	0	10	3	21	23	50	445

							TSP ($\mu g/m^{-3}$) in each size range									
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes	
2	1	1	1	9	7	25	12	21	32	28	33	9	14	5	440	For observed pairing; 2 ignored
					14	35	9	20	30	27	48	9	22	10	495	
					22	35	16	27	37	32	44	10	5	20	405	
				10	6	30	6	15	21	18	29	10	21	30	690	
					21	0	15	16	-10	23	23	11	6	15	550	
				11	6	50	4	11	19	17	7	11	15	20	550	
					15	45	12	18	22	20	26	11	23	0	475	
		2	3	8	23	25	-10	20	24	42	44	9	7	20	475	
				9	8	0	9	20	33	26	37	9	14	45	405	
		3	3	11	16	45	14	23	27	19	27	11	23	0	415	
				13	14	15	7	15	44	15	46	13	22	15	480	
			4	9	0	5	7	20	25	24	-10	9	8	10	485	
					9	35	14	23	47	42	52	9	15	35	360	
					16	5	12	29	32	39	61	9	23	0	455	
					23	15	25	34	52	39	71	10	3	15	300	
				10	11	30	13	13	15	9	20	10	22	40	670	
					22	10	8	17	21	18	25	11	7	30	650	
				11	7	55	5	16	21	26	27	11	16	30	555	
		4	3	9	15	25	21	10	40	50	83	9	22	30	425	
					22	40	36	48	-10	61	106	10	2	55	255	
				10	7	0	33	36	45	49	85	10	14	0	420	
					21	35	11	22	25	21	30	11	7	0	565	
				11	7	25	5	17	17	20	41	11	15	55	510	
			4	11	16	15	15	36	31	26	35	11	23	0	415	
2	2	1	1	8	23	45	0	17	4	5	9	9	7	5	440	For observed pairing; 4 ignored
				9	7	30	30	30	41	75	66	9	14	10	400	
					14	50	29	14	20	44	45	9	23	10	500	
					23	30	0	10	27	26	31	10	7	10	460	
				10	7	40	0	37	85	27	36	10	14	15	395	
					14	30	0	36	32	85	159	10	23	0	510	
					23	30	0	31	5	87	26	11	7	5	455	
				11	7	30	0	69	21	102	24	11	12	15	285	
					14	30	0	117	26	59	30	11	23	35	545	
		2	2	9	0	25	11	26	1	27	22	9	7	55	450	
					8	25	0	51	76	101	16	9	15	5	400	
					15	30	49	71	24	64	86	9	23	45	495	
				10	0	10	51	13	19	61	34	10	3	40	210	
					9	0	20	31	13	61	59	10	14	45	345	
					15	0	51	87	58	142	268	10	23	45	285	

							TSP ($\mu g/m^{-3}$) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
2	2	1	1	11	0	5	0	14	9	23	27	11	7	45	470
					8	5	0	143	9	32	38	11	14	45	400
					15	0	0	52	74	44	35	11	23	45	525
		4	4	9	2	10	0	41	0	68	2	9	4	40	150
					9	10	0	38	11	15	11	9	17	15	485
		5	4	9	18	35	0	25	56	37	0	10	0	20	345
				10	0	45	0	20	10	45	41	10	8	50	495
					9	25	45	22	10	91	41	10	15	10	345
					15	30	0	22	4	22	15	11	0	10	520
				11	0	30	0	16	3	55	18	11	8	15	475
					8	40	23	45	5	45	20	11	15	10	390
					15	20	0	43	37	43	41	11	23	50	510
2	3	1	3	11	14	45	2	7	0	5	1	11	23	10	505
					23	30	3	7	4	11	6	12	7	20	470
				12	7	55	14	15	13	13	16	12	14	10	375
					14	30	2	1	14	15	23	12	23	20	530
					23	35	12	12	20	7	2	13	6	55	450
				13	7	15	3	4	2	3	9	13	15	25	490
					15	40	2	2	3	14	14	13	23	45	485
			4	11	0	15	-10	-10	-10	-10	-10	11	6	50	395
					9	55	8	8	23	18	13	11	14	30	275
		2	1	11	2	5	10	11	8	10	18	11	7	55	350
					10	10	7	5	5	24	22	11	15	0	290
					15	15	9	10	1	15	26	11	23	45	510
				12	0	0	2	3	3	43	8	12	8	0	480
					8	25	5	8	0	7	7	12	14	40	375
					14	55	2	3	4	4	19	12	23	50	535
				13	0	10	8	10	1	11	19	13	4	10	240
					8	0	7	9	0	7	8	13	15	45	465
					15	55	3	1	1	19	12	14	0	0	485
		3	2	11	1	0	0	0	4	-10	-10	11	7	20	380
					10	25	6	10	6	8	13	11	15	25	300
					15	40	12	18	8	7	36	11	19	40	240
				12	1	5	4	2	9	13	5	12	8	35	450
					9	0	2	4	3	25	4	12	15	5	365
					15	20	17	21	1	21	35	12	19	20	240
				13	1	5	7	9	3	8	12	13	8	10	425
					8	30	3	2	90	2	2	13	16	15	465
					16	25	5	2	2	12	12	14	20	25	240
		4	3	11	1	25	8	9	10	6	17	11	7	45	380
					10	35	6	7	5	15	16	11	15	45	310

For observed pairing; 4 ignored

							TSP (µg/ m^{-3}) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
2	3	4	4	11	16	5	9	9	22	54	16	12	0	20	495
				12	1	50	5	4	16	24	14	12	9	5	435
					9	15	15	1	19	3	65	12	15	25	370
					15	40	4	5	9	16	3	13	0	30	530
				13	0	50	16	20	27	2	1	13	8	35	445
					8	50	2	4	1	2	1	13	16	30	460
					16	45	11	29	0	3	14	14	0	30	465
3	1	1	1	13	23	30	5	15	25	13	29	14	6	45	495
				14	7	20	9	22	41	31	43	14	12	20	300
				21	17	55	26	22	48	54	72	21	22	10	295
				22	7	20	11	11	-10	23	22	22	14	30	430
					14	55	12	20	-10	30	29	22	19	25	270
					22	45	14	17	21	17	23	23	6	15	450
				23	6	35	11	15	21	21	29	23	13	55	450
					14	15	31	32	43	42	66	23	17	30	195
				24	6	35	8	32	48	26	31	24	12	20	345
			4	13	15	50	7	10	22	13	25	13	23	50	480
				14	0	10	19	22	10	18	30	14	7	45	455
					8	0	12	25	34	31	47	14	13	15	315
					16	15	24	40	78	45	56	14	22	15	240
					23	30	6	32	51	39	54	15	9	15	255
				15	9	40	4	13	23	20	14	15	16	0	340
		2	1	13	15	0	9	15	47	24	35	13	22	45	465
				14	14	30	38	36	54	53	74	14	19	0	270
			2	13	15	10	13	19	23	21	19	13	22	45	455
					23	35	9	24	33	22	6	14	6	45	430
				14	7	20	10	34	38	63	-10	14	12	20	300
					14	30	35	45	47	46	-10	14	19	0	270
				15	8	50	2	-10	-10	-10	-10	15	15	0	410
				21	18	25	9	13	16	14	-10	22	7	40	795
				22	8	10	10	20	16	18	24	22	15	10	420
					15	25	9	14	15	17	22	22	23	0	455
					23	20	13	20	20	18	26	23	6	50	450
				23	7	15	20	15	22	22	26	23	14	30	435
					14	45	16	16	22	18	26	23	22	45	480
					22	10	14	14	19	19	21	24	6	10	480
				24	7	25	17	14	24	19	32	24	14	40	435
		3	3	13	22	35	6	19	31	20	32	14	6	10	455
				14	6	30	5	22	-10	26	-10	14	12	0	430
					14	45	8	24	28	27	35	14	21	50	425
					22	15	8	31	46	33	22	15	7	0	315

Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
							TSP ($\mu g/ m^{-3}$) in each size range								
3	1	3	3	15	7	40	-10	17	19	14	25	15	14	20	440
				21	16	15	16	15	24	28	28	22	9	10	101
				22	8	25	10	35	13	40	42	22	12	55	270
					16	5	42	24	28	26	23	22	23	40	455
					23	55	37	30	35	38	90	23	7	30	455
				23	7	45	15	27	24	25	32	23	15	0	435
					15	20	45	35	68	46	69	23	20	5	285
				24	8	3	27	28	36	38	44	24	12	3	240
		4	4	21	17	30	10	15	4	16	26	22	8	25	895
				22	9	45	9	18	17	17	-10	22	16	30	405
					16	50	21	25	-10	24	32	22	0	15	445
				23	0	30	17	17	27	28	53	23	0	80	450
					8	15	17	16	23	20	25	23	15	35	440
					15	40	26	24	25	26	28	23	20	25	285
				24	8	30	15	16	17	55	26	24	15	15	405
3	2	6	4	24	0	0	12	13	36	21	58	24	8	17	497
		6	4	15	15	5	0	32	26	51	62	15	22	55	470
					23	15	57	29	32	49	44	16	7	15	480
				16	7	40	0	27	22	32	22	16	14	45	445
							0	27	22	32	22	16	14	45	445
					15	0	0	31	23	36	31	16	22	40	460
					22	55	0	35	15	33	18	17	7	0	485
				17	7	20	13	29	31	16	44	17	14	40	440
					15	0	0	30	29	27	27	17	22	55	475
					23	15	0	30	19	36	40	18	7	15	480
				18	7	40	0	26	27	40	23	18	14	35	415
		7	2	15	15	40	0	30	18	22	31	15	23	30	470
				16	0	15	18	54	44	73	84	16	8	0	465
					8	20	0	45	27	52	54	16	15	15	475
					15	30	0	32	16	38	33	16	23	10	460
					23	30	0	29	20	33	-10	17	7	35	485
				17	8	0	0	34	28	56	97	17	15	15	435
					15	30	0	20	21	35	39	17	23	30	480
					23	50	0	23	0	29	36	18	7	50	480
				18	8	15	35	48	44	64	71	18	15	0	405
		8	1	15	16	15	0	188	192	314	643	15	17	45	90
				16	1	0	13	55	28	41	43	16	8	30	450
					11	5	0	112	116	230	314	16	15	45	280
					16	0	0	40	33	58	32	16	23	45	465

							TSP (μg/ m^{-3}) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
3	2	8	1	17	0	5	0	106	88	97	105	17	8	20	495
					8	35	0	31	39	71	80	17	16	10	455
					16	30	1	37	31	46	77	18	0	10	460
				18	0	30	7	10	23	31	33	18	8	25	475
					8	45	45	65	96	102	167	18	15	30	405
3	3	5	1	17	15	25	9	10	19	10	23	17	23	0	455
					23	15	2	2	5	14	17	18	7	10	465
				18	7	40	4	3	3	14	27	18	16	40	540
					16	55	20	29	146	26	37	18	20	55	240
					23	45	0	0	1	1	23	19	7	10	445
				19	7	50	6	8	7	21	23	19	15	35	465
					15	50	15	24	0	4	22	19	23	10	380
					23	25	8	7	19	7	62	20	7	10	465
				20	7	45	3	5	0	0	9	20	14	55	430
		6	2	17	15	45	4	3	0	11	14	17	23	30	465
					23	50	15	17	20	0	18	18	7	50	480
				18	8	15	7	13	5	6	8	18	17	5	530
					17	20	0	2	0	15	0	19	0	0	400
				19	0	15	2	5	1	9	0	19	8	5	470
					8	30	10	11	13	4	9	19	16	5	455
					16	25	2	0	14	14	3	19	23	45	440
				20	0	0	2	4	8	0	0	20	7	55	475
					8	20	1	0	0	7	2	20	15	20	420
		7	4	17	16	5	12	16	10	0	12	17	20	5	240
				18	17	45	16	17	0	186	69	18	23	30	345
				19	0	45	2	4	3	4	0	19	8	45	480
					9	10	9	10	147	16	22	19	16	30	440
					16	40	13	17	18	0	11	20	0	10	450
				20	0	30	1	1	3	22	2	20	8	30	480
					8	50	5	37	1	25	0	20	15	40	410
		8	3	17	16	30	5	9	2	15	8	18	0	40	490
				18	1	0	5	27	7	5	0	18	8	35	455
					9	0	3	19	0	5	1	18	17	55	535
				19	2	45	10	23	7	9	10	19	9	30	405
					9	40	14	14	12	45	25	19	16	50	430
					17	5	0	0	0	6	14	20	0	40	455
				20	0	55	6	12	3	8	7	20	9	0	485
					9	20	0	0	0	9	0	20	16	5	405
4	1	1	1	21	17	55	26	22	48	54	72	21	22	10	295
				22	7	20	11	11	-10	23	22	22	14	30	430
					14	55	12	20	-10	30	20	22	19	25	270
					22	45	14	17	21	17	23	23	6	15	450

							TSP ($\mu g/ m^{-3}$) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
4	1	1	1	23	6	35	11	15	21	21	29	23	13	35	440
					14	15	31	32	43	42	66	23	17	30	195
				24	6	35	8	32	48	26	31	24	12	20	345
		2	2	21	18	25	9	13	16	14	-10	22	7	40	795
				22	8	10	10	20	16	18	24	22	15	10	420
					15	25	9	14	15	17	22	22	23	0	455
					23	20	13	20	20	18	26	23	6	50	450
				23	7	15	20	15	22	22	26	23	14	30	435
					14	45	16	16	22	18	26	23	22	45	480
					22	10	14	14	19	19	21	24	6	10	480
				24	7	25	17	14	24	19	32	24	14	40	435
		3	3	21	16	15	16	15	24	28	28	22	9	10	101
				22	8	25	10	35	13	40	42	22	12	55	270
					16	5	42	24	28	26	53	22	23	40	455
					23	55	37	30	35	38	90	23	7	30	455
				23	7	45	15	27	24	25	32	23	15	0	435
					15	20	45	35	68	46	69	23	20	5	285
				24	8	3	27	28	36	38	44	24	12	3	240
		4	4	21	17	30	10	15	4	16	26	22	8	25	895
				22	9	45	9	18	17	17	-10	22	16	30	405
					16	50	21	25	-10	24	32	23	0	15	445
				23	0	30	17	17	27	28	53	23	8	0	450
					8	15	17	16	23	20	25	23	15	35	440
					15	40	26	24	25	26	28	23	20	25	285
				24	8	30	15	16	17	55	26	24	15	15	405
4	2	1	1	1	6	35	0	17	4	35	26	1	14	20	465
					14	45	0	12	43	10	39	1	19	15	270
					22	30	44	-10	35	18	47	2	6	10	460
				2	6	30	0	0	30	12	22	2	14	0	450
					14	25	0	9	25	33	18	2	22	0	455
					22	20	36	33	4	17	7	3	6	10	470
				3	6	30	341	27	5	14	8	3	14	0	450
				30	17	30	75	23	29	90	170	30	23	15	345
					23	40	0	52	37	25	23	1	6	15	385
		2	2	1	0	15	0	20	17	43	28	1	6	50	395
					7	10	0	13	20	6	6	1	15	0	465
					15	15	31	17	14	13	19	1	22	50	455
					23	10	55	89	87	52	21	2	6	45	455
				2	7	5	0	126	6	114	16	2	8	35	90
					15	5	64	16	7	43	52	2	22	35	450
					22	55	0	13	15	110	22	3	7	0	485

							TSP ($\mu g/ m^{-3}$) in each size range								
Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5	Ending day	Ending hour	Ending minute	Elapsed minutes
4	2	2	2	3	7	15	50	15	23	26	45	3	14	20	425
				30	18	0	0	12	65	39	0	30	23	50	350
		3	3	1	0	40	18	30	31	43	28	1	7	15	395
					7	35	0	21	5	25	18	1	15	20	465
					15	35	0	14	31	8	29	1	23	25	470
					23	50	0	25	54	35	67	2	7	10	440
				2	7	25	22	19	21	23	26	2	15	15	470
					15	30	0	38	37	37	57	2	23	5	395
					23	30	0	11	5	8	30	3	7	20	470
				3	7	45	13	39	111	18	37	3	14	50	425
				30	18	30	0	26	12	36	6	1	0	20	350
		4	4	1	16	40	93	28	34	65	88	2	0	0	440
				2	0	45	129	42	0	-10	129	2	7	45	420
					8	0	52	38	37	50	139	2	15	50	470
					16	10	0	64	69	80	5	2	20	10	240
				3	0	20	0	19	13	7	23	3	8	5	465
					8	25	0	24	11	33	48	3	15	15	470
4	3	1	1	1	7	30	9	22	8	20	11	1	15	0	450
					15	15	16	35	3	28	14	1	22	50	455
					23	5	5	17	0	23	5	2	7	15	490
				2	7	40	24	35	1	33	11	2	14	55	435
				30	15	10	14	20	13	2	9	30	22	55	465
					23	15	16	18	5	16	16	31	7	10	475
				31	7	35	23	39	25	19	13	31	15	0	445
					15	10	0	12	1	0	5	31	22	45	455
					23	0	18	40	0	18	16	1	7	15	495
		2	4	1	8	0	20	30	0	23	22	1	15	25	445
					15	35	19	24	15	44	42	1	23	15	460
					23	25	19	20	13	0	31	2	7	50	505
				2	8	15	43	51	70	79	108	2	15	15	420
				30	15	30	4	10	48	7	9	30	23	25	475
					23	40	11	16	9	18	23	31	8	0	500
				31	8	20	5	7	8	10	8	31	15	20	420
					15	30	5	8	12	20	20	31	23	10	460
					23	25	18	33	13	19	13	1	7	40	495
		3	3	1	8	30	32	94	36	51	5	1	10	45	135
					16	0	13	35	5	51	17	1	20	0	240
				2	0	30	21	31	27	56	48	2	8	25	475
					8	45	20	38	41	90	0	2	15	35	410
				30	15	55	14	18	12	24	14	30	23	50	465

Mine	Trip	Location number	Sampler number	Day	Starting hour	Starting minute	TSP ($\mu g/m^{-3}$) in each size range					Ending day	Ending hour	Ending minute	Elapsed minutes
							Smallest TSP1	TSP2	TSP3	TSP4	Largest TSP5				
4	3	3	3	31	0	5	7	11	26	4	34	31	8	35	510
					8	55	12	27	6	8	44	31	15	45	410
					15	55	10	16	6	14	118	31	23	40	465
					23	55	24	35	9	25	12	1	8	10	495
		4	2	1	0	25	30	38	19	30	46	1	8	40	495
					8	50	21	30	7	45	24	1	16	10	440
					16	25	25	60	0	99	1	1	20	25	240
				2	0	55	10	17	6	33	24	2	9	0	485
				30	16	15	20	56	19	23	18	31	0	15	480
				31	0	30	13	19	24	24	49	31	9	5	515
					9	25	9	26	13	17	18	31	16	5	400
					16	35	16	19	9	55	23	1	0	5	450

WEATHER DATA

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
1	1	24	16	14.0	180.	90.0	0	C
			17	16.5	185.	90.0	0	C
			18	16.0	195.	87.0	0	C
			19	6.0	190.	80.0	0	B
			20	3.2	-2.	74.0	0	B
			21	1.8	-2.	72.0	0	F
			22	1.7	-2.	69.0	0	F
			23	1.8	-2.	66.0	0	F
		25	0	4.8	180.	65.0	0	F
			1	6.3	240.	67.0	0	F
			2	5.5	30.	64.0	0	F
			3	4.6	45.	61.0	0	F
			4	3.6	60.	60.0	0	F
			5	4.0	75.	59.0	0	F
			6	2.8	-2.	60.0	0	B
			7	3.2	-2.	67.0	0	B
			8	9.9	135.	70.0	0	C
			9	14.2	135.	70.0	0	C
			10	15.2	135.	73.0	0	C
			11	18.0	150.	74.0	0	C
			12	17.0	150.	79.0	0	C
			13	19.2	240.	62.0	0	D
			14	19.0	300.	62.0	0	D
			15	16.2	285.	68.0	0	D
			16	10.0	300.	67.0	0	D
			17	7.7	285.	71.0	0	D
			18	4.9	-2.	71.0	0	D
			19	2.5	-2.	69.0	0	D
			20	3.0	-2.	67.0	0	D
			21	7.0	30.	60.0	0	D
			22	6.0	-2.	60.0	0	D
			23	11.0	285.	56.0	0	D
		26	0	11.0	300.	52.0	0	D
			1	12.0	285.	51.0	0	D
			2	10.1	270.	50.0	0	D
			3	9.8	270.	48.0	0	D
			4	5.8	265.	48.0	0	D
			5	8.7	275.	48.0	0	D
			6	8.8	270.	48.0	0	D
			7	9.2	255.	51.0	0	D
			8	10.0	255.	53.0	0	B
			9	11.4	270.	58.0	0	B
			10	8.8	270.	62.0	0	B
			11	11.0	245.	65.0	0	B
			12	11.0	240.	68.0	0	B
			13	8.5	240.	72.0	0	B
			14	8.5	240.	72.0	0	B
			15	8.5	225.	70.0	0	B
			16	7.5	-2.	73.0	0	B
			17	5.5	180.	58.0	0	C

VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
1	26	17	7.0	240.	73.0	0	B
		18	6.0	240.	73.0	0	B
		19	4.9	210.	72.0	0	B
			7.5	-2.	56.0	0	C
		20	13.0	210.	60.0	0	C
		21	9.5	285.	55.0	0	D
		22	8.8	300.	53.0	0	D
		23	3.2	-2.	51.0	0	D
	27	0	3.3	-2.	50.0	0	F
		1	3.0	-2.	51.0	0	F
		2	2.8	-2.	52.0	0	F
		3	2.3	-2.	51.0	0	F
		4	4.0	-2.	50.0	0	E
		6	3.7	-2.	51.0	0	E
		7	2.9	-2.	53.0	0	B
		8	4.8	105.	55.0	0	C
		9	5.0	180.	55.0	0	C
		10	5.2	-2.	55.0	1	D
		11	3.0	-2.	60.0	1	D
		12	4.3	-2.	68.0	0	B
		13	8.0	60.	68.0	0	B
		14	9.5	60.	66.0	0	B
		15	8.5	330.	64.0	1	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
1	2	21	8	7.3	180.	-18.0	-2	D
			9	9.3	165.	-16.0	-2	B
			10	9.7	180.	-14.0	-2	B
			11	10.8	170.	-11.0	-2	B
			12	9.0	150.	-9.0	-2	B
			13	7.0	150.	-4.0	-2	B
			14	6.4	120.	.0	-2	A
			15	4.8	125.	-1.0	-2	A
			16	5.2	110.	-9.0	-2	B
			17	5.1	120.	-11.0	-2	E
			18	3.8	125.	-12.0	-2	F
			19	.6	-2.	-16.0	-2	F
			20	1.1	320.	-16.0	-2	F
			21	1.0	-2.	-15.0	-2	F
			22	1.8	-2.	-14.0	-2	F
			23	3.4	300.	-17.0	-2	F
		22	0	2.1	295.	-19.0	-2	F
			1	3.2	295.	-18.0	-2	F
			2	2.7	295.	-20.0	-2	F
			3	1.3	300.	-19.0	-2	F
			4	3.0	280.	-20.0	-2	F
			5	2.9	290.	-20.0	-2	F
			6	2.3	300.	-21.0	-2	F
			7	2.8	330.	-20.0	-2	B
			8	2.8	330.	-13.0	-2	A
			9	2.5	0.	-10.0	-2	A
			10	6.5	350.	-8.0	-2	B
			11	12.2	0.	-7.0	-2	D
			12	13.6	0.	-5.0	-2	D
			13	11.2	0.	-5.0	-2	C
			14	8.8	0.	-5.0	-2	C
			15	10.2	0.	-5.0	-2	C
			16	9.2	345.	-5.0	-2	C
			17	10.1	345.	-5.0	-2	D
			18	8.7	330.	-5.0	-2	D
			19	8.9	355.	-5.0	-2	D
			20	8.1	355.	-5.0	-2	D
			21	6.0	350.	-5.0	-2	D
			22	5.0	0.	-6.0	-2	D
			23	5.2	350.	-6.0	-2	D
		23	0	3.8	0.	-6.0	-2	D
			1	7.1	355.	-7.0	-2	D
			2	7.7	350.	-8.0	-2	D
			3	7.1	350.	-8.0	-2	D
			4	6.1	0.	-8.0	-2	D
			5	5.2	350.	-8.0	-2	D
			6	4.7	340.	-8.0	-2	D
			7	2.9	-2.	-8.0	-2	D
			8	2.6	-2.	-5.0	-2	B
			9	5.9	290.	-3.0	-2	C
			10	7.4	295.	.0	-2	C

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
1	2	23	11	10.6	295.	-2.0	-2	C
			12	14.9	300.	-3.0	-2	D
			13	15.3	300.	-3.0	-2	D
			14	12.1	295.	-5.0	-2	D
			15	13.6	300.	-6.0	-2	D
			16	14.7	300.	-9.0	-2	D
			17	10.5	300.	-9.0	-2	D
			18	6.8	280.	-11.0	-2	D
			19	8.7	285.	-12.0	-2	D
			20	8.0	275.	-13.0	-2	D
			21	9.0	275.	-14.0	-2	D
			22	10.0	295.	-14.0	-2	D
			23	6.0	300.	-18.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. oF	Precip. (inches)	Stability Class
1	3	19	0	12.7	265.	10.0	-2	D
			1	16.2	260.	10.0	-2	D
			2	16.3	255.	10.0	-2	D
			3	14.6	260.	9.0	-2	D
			4	15.0	270.	8.0	-2	D
			5	16.7	275.	6.0	-2	D
			6	13.2	265.	5.0	-2	D
			7	14.3	275.	5.0	-2	D
			8	14.7	265.	5.0	-2	D
			9	18.4	260.	6.0	-2	D
			10	20.1	265.	7.0	-2	D
			11	22.2	270.	7.0	-2	D
			12	23.3	275.	6.0	-2	D
			13	24.2	275.	5.0	-2	D
			14	23.9	280.	4.0	-2	D
			15	21.6	280.	3.0	-2	D
			16	21.1	280.	2.0	-2	D
			17	24.6	280.	1.0	-2	D
			18	24.0	280.	.0	-2	D
			19	27.0	290.	.0	-2	D
			20	21.8	290.	-1.0	-2	D
			21	23.5	280.	-2.0	-2	D
			22	25.0	280.	-3.0	-2	D
			23	24.0	285.	-3.0	-2	D
		20	0	24.4	285.	-4.0	-2	D
			1	24.6	285.	-5.0	-2	D
			2	25.8	280.	-6.0	-2	D
			3	19.8	285.	-6.0	-2	D
			4	18.4	280.	-6.0	-2	D
			5	17.3	285.	-5.0	-2	D
			6	19.5	290.	-5.0	-2	D
			7	18.0	275.	-4.0	-2	D
			8	9.4	275.	-2.0	-2	C
			9	10.8	285.	.0	-2	C
			10	13.7	280.	3.0	-2	D
			11	16.3	280.	5.0	-2	D
			12	18.0	285.	7.0	-2	D
			13	22.8	285.	8.0	-2	D
			14	20.2	290.	8.0	-2	D
			15	14.5	275.	7.0	-2	D
			16	8.6	270.	5.0	-2	C
			17	11.9	270.	4.0	-2	C
			18	8.4	275.	2.0	-2	C
			19	3.2	-2.	1.0	-2	F
			20	5.7	-2.	1.0	-2	F
			21	3.7	-2.	1.0	-2	F
			22	6.2	215.	.0	-2	F
			23	3.8	-2.	-3.0	-2	F
		21	0	10.7	210.	.0	-2	E
			1	6.5	-2.	.0	-2	F
			2	10.5	185.	.0	-2	E

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
1	3	21	3	10.0	185.	1.0	-2	E
			4	9.4	190.	2.0	-2	E
			5	10.7	200.	2.0	-2	E
			6	10.3	195.	3.0	-2	E
			7	10.6	195.	3.0	-2	E
			8	13.1	190.	5.0	-2	D
			9	14.3	195.	8.0	-2	D
			10	11.9	195.	14.0	-2	D
			11	17.0	195.	15.0	-2	D
			12	8.4	180.	18.0	-2	C
			13	8.5	-2.	21.0	-2	D
			14	8.8	-2.	19.0	-2	D
			15	10.3	190.	15.0	-2	D
			16	11.1	195.	16.0	-2	D
			17	6.0	-2.	16.0	-2	D
			18	7.1	-2.	16.0	-2	D
			19	8.9	-2.	18.0	-2	D
			20	5.1	-2.	19.0	-2	D
			21	3.8	-2.	18.0	-2	D
			22	5.2	-2.	16.0	-2	D
			23	5.1	-2.	17.0	-2	D
		22	0	2.4	-2.	16.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
2	1	8	23	15.8	120.	60.0	0	D
		9	0	15.0	120.	59.0	0	D
			1	15.0	130.	58.0	0	D
			2	15.0	130.	58.0	0	D
			3	15.0	135.	57.0	0	D
			4	16.9	130.	57.0	0	D
			5	17.0	130.	52.0	0	D
			6	18.0	135.	51.0	0	D
			7	19.8	140.	53.0	0	D
			8	23.8	150.	52.0	0	D
			9	21.0	165.	52.0	0	D
			10	20.0	160.	50.0	0	D
			11	16.0	165.	51.0	0	D
			12	14.7	165.	53.0	0	D
			13	18.3	165.	60.0	0	D
			14	16.9	150.	68.0	0	C
			15	18.8	165.	70.0	0	D
			16	18.4	170.	72.0	0	D
			17	16.0	160.	73.0	0	D
			18	13.5	140.	73.0	0	D
			19	13.9	140.	73.0	0	D
			20	13.9	140.	71.0	0	D
			21	11.0	90.	69.0	0	D
			22	18.2	150.	67.0	0	D
			23	21.0	165.	63.0	0	D
		10	0	20.0	160.	60.0	0	D
			1	6.0	-2.	60.0	1	D
			2	11.5	210.	60.0	1	D
			3	13.6	240.	58.0	1	D
			4	10.0	-2.	59.0	1	D
			5	9.7	-2.	58.0	1	D
			6	9.0	285.	58.0	1	D
			7	7.4	255.	58.0	1	D
			8	4.1	210.	71.0	1	D
			9	5.0	285.	70.0	0	D
			10	5.8	290.	72.0	0	D
			11	7.4	315.	77.0	0	D
			12	8.0	315.	78.0	0	D
			13	10.8	330.	80.0	0	D
			14	10.5	10.	79.0	0	D
			15	13.0	350.	75.0	0	D
			16	15.0	150.	78.0	0	D
			17	13.2	0.	80.0	0	D
			18	13.6	15.	78.0	0	D
			19	11.3	15.	72.0	0	D
			20	11.0	30.	72.0	1	D
			21	10.0	355.	70.0	1	D
			22	11.8	270.	61.0	1	D
			23	9.0	255.	58.0	1	D
		11	0	11.0	50.	59.0	1	D
			1	11.8	0.	59.0	1	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
2	1	11	2	8.0	285.	58.0	1	D
			3	10.8	320.	57.0	1	D
			4	13.8	330.	55.0	1	D
			5	10.0	330.	53.0	1	D
			6	9.4	245.	53.0	0	D
			7	10.7	30.	53.0	0	D
			8	8.5	55.	55.0	0	D
			9	11.4	30.	53.0	0	D
			10	10.6	40.	51.0	0	D
			11	13.5	45.	51.0	0	D
			12	11.5	60.	55.0	0	D
			13	12.0	75.	59.0	0	D
			14	12.0	75.	60.0	0	D
			15	12.0	75.	62.0	0	D
			16	11.5	60.	63.0	0	C
			17	11.8	75.	65.0	0	C
			18	13.0	60.	65.0	0	D
			19	12.0	45.	62.0	0	D
			20	12.2	60.	59.0	0	D
			21	12.7	60.	55.0	0	D
			22	10.0	60.	50.0	0	D
			23	7.5	60.	48.0	0	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. ^{o}F	Precip. (inches)	Stability Class
2	2	8	23	12.7	330.	20.0	0	D
		9	0	14.4	315.	19.0	0	D
			1	14.6	320.	18.0	0	D
			2	13.4	320.	17.0	0	D
			3	9.5	310.	15.0	0	E
			4	10.2	300.	14.0	0	E
			5	10.1	300.	13.0	0	E
			6	8.9	300.	12.0	0	E
			7	9.3	300.	12.0	0	D
			8	10.6	300.	13.0	0	B
			9	12.1	315.	17.0	0	C
			10	18.0	340.	21.0	0	C
			11	17.1	335.	24.0	0	C
			12	17.3	335.	25.0	0	C
			13	16.5	330.	28.0	0	C
			14	20.4	330.	28.0	0	C
			15	20.9	330.	29.0	0	C
			16	18.9	330.	29.0	0	C
			17	11.5	330.	27.0	0	C
			18	9.5	305.	24.0	0	E
			19	9.1	300.	22.0	0	E
			20	8.5	290.	21.0	0	E
			21	7.9	290.	19.0	0	E
			22	8.7	290.	20.0	0	E
			23	6.4	-2.	19.0	0	F
		10	0	6.5	-2.	15.0	0	F
			1	6.0	-2.	14.0	0	F
			2	2.1	-2.	13.0	0	F
			3	2.9	-2.	11.0	0	F
			4	3.0	-2.	13.0	0	F
			5	3.3	-2.	14.0	0	F
			6	1.8	-2.	10.0	0	F
			7	1.8	-2.	10.0	0	D
			8	4.5	250.	15.0	0	B
			9	7.9	260.	19.0	0	C
			10	8.1	270.	25.0	0	B
			11	9.3	270.	27.0	0	B
			12	7.6	280.	30.0	0	B
			13	11.1	305.	32.0	0	B
			14	11.0	300.	34.0	0	B
			15	11.9	300.	34.0	0	C
			16	10.3	315.	32.0	0	B
			17	9.1	285.	30.0	0	D
			18	10.7	290.	28.0	0	D
			19	9.0	305.	25.0	0	E
			20	8.5	305.	22.0	0	E
			21	8.5	300.	22.0	0	E
			22	7.4	295.	21.0	0	E
			23	6.6	285.	19.0	0	E
		11	0	7.0	300.	19.0	0	E
			1	8.5	-2.	19.0	0	E

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. $^{\circ}$F	Precip. (inches)	Stability Class
2	2	11	2	7.1	335.	19.0	0	E
			3	8.0	340.	17.0	0	E
			4	5.0	-2.	15.0	0	F
			5	5.4	-2.	15.0	0	F
			6	3.9	0.	12.0	0	F
			7	2.5	0.	11.0	0	B
			8	3.3	-2.	11.0	0	A
			9	2.0	-2.	16.0	0	A
			10	4.5	60.	17.0	0	B
			11	4.5	-2.	20.0	0	B
			12	5.7	100.	23.0	0	B
			13	7.0	90.	26.0	0	B
			14	7.8	115.	28.0	0	B
			15	9.8	135.	29.0	0	B
			16	9.3	135.	27.0	0	B
			17	9.9	125.	23.0	0	D
			18	10.1	130.	19.0	0	E
			19	10.0	130.	16.0	0	E
			20	10.5	145.	15.0	0	E
			21	12.4	145.	13.0	0	D
			22	12.4	145.	12.0	0	D
			23	12.6	130.	12.0	0	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
2	3	11	0	4.0	50.	-19.0	-2	F
			1	3.0	80.	-20.0	-2	F
			2	4.0	60.	-19.0	-2	F
			3	.0	0.	-19.0	-2	F
			4	3.0	70.	-19.0	-2	F
			5	.0	0.	-19.0	-2	F
			6	4.0	70.	-19.0	-2	F
			7	5.0	70.	-19.0	-2	F
			8	6.0	60.	-19.0	-2	F
			9	4.0	60.	-18.0	-2	B
			10	.0	0.	-14.0	-2	B
			11	.0	0.	-11.0	-2	B
			12	.0	0.	-8.0	-2	B
			13	.0	0.	-3.0	-2	A
			14	.0	0.	.0	-2	A
			15	3.0	70.	2.0	-2	A
			16	4.0	60.	2.0	-2	B
			17	4.0	130.	1.0	-2	D
			18	6.0	120.	-1.0	-2	D
			19	5.0	140.	-1.0	-2	D
			20	6.0	120.	-2.0	-2	L
			21	.0	0.	-4.0	-2	D
			22	.0	0.	-5.0	-2	D
			23	5.0	80.	-6.0	-2	D
		12	0	3.0	80.	-3.0	-2	D
			1	3.0	120.	1.0	-2	D
			2	.0	0.	3.0	-2	D
			3	.0	0.	4.0	-2	D
			4	3.0	130.	4.0	-2	D
			5	4.0	100.	4.0	-2	D
			6	.0	0.	5.0	-2	D
			7	3.0	140.	-1.0	-2	D
			8	3.0	170.	7.0	-2	B
			9	6.0	170.	8.0	-2	C
			10	5.0	170.	9.0	-2	C
			11	3.0	140.	11.0	-2	B
			12	6.0	230.	14.0	-2	C
			13	5.0	240.	11.0	-2	C
			14	3.0	240.	19.0	-2	B
			15	4.0	300.	20.0	-2	B
			16	6.0	340.	21.0	-2	C
			17	14.0	330.	16.0	-2	D
			18	13.0	310.	14.0	-2	D
			19	13.0	330.	13.0	-2	D
			20	11.0	320.	12.0	-2	D
			21	13.0	320.	11.0	-2	D
			22	11.0	330.	11.0	-2	D
			23	12.0	320.	9.0	-2	D
		13	0	18.0	330.	8.0	-2	D
			1	13.0	330.	7.0	-2	D
			2	16.0	340.	8.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
2	3	13	3	11.0	360.	6.0	-2	D
			4	12.0	350.	5.0	-2	D
			5	11.0	350.	5.0	-2	D
			6	9.0	350.	4.0	-2	D
			7	10.0	350.	5.0	-2	D
			8	12.0	330.	5.0	-2	D
			9	10.0	350.	4.0	-2	D
			10	6.0	330.	5.0	-2	C
			11	8.0	330.	6.0	-2	C
			12	6.0	340.	6.0	-2	C
			13	6.0	320.	7.0	-2	C
			14	6.0	300.	7.0	-2	C
			15	9.0	310.	7.0	-2	C
			16	4.0	300.	9.0	-2	B
			17	4.0	300.	7.0	-2	C
			18	4.0	320.	5.0	-2	D
			19	.0	0.	2.0	-2	D
			20	4.0	180.	-1.0	-2	D
			21	3.0	240.	-1.0	-2	D
			22	.0	0.	-2.0	-2	D
			23	.0	0.	-5.0	-2	D
		14	0	.0	0.	-5.0	-2	D
			1	.0	0.	-1.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
3	1	13	12	7.0	315.	51.0	0	D
			13	7.0	330.	51.0	0	D
			14	6.0	345.	52.0	0	D
			15	6.8	340.	55.0	0	D
			16	5.2	315.	58.0	0	D
			17	11.0	350.	55.0	0	D
			18	8.8	10.	55.0	0	D
			19	9.2	10.	54.0	0	D
			20	7.6	15.	52.0	0	D
			21	5.2	40.	51.0	0	E
			22	4.8	45.	49.0	0	E
			23	3.0	-2.	48.0	0	F
		14	0	3.0	-2.	46.0	0	F
			1	3.0	-2.	46.0	0	F
			2	5.8	90.	47.0	0	E
			3	8.0	80.	47.0	0	D
			4	3.7	-2.	46.0	0	E
			5	5.0	75.	45.0	0	E
			6	8.0	105.	47.0	0	C
			7	12.0	105.	50.0	0	C
			8	14.8	105.	52.0	0	D
			9	15.0	110.	53.0	0	D
			10	12.0	105.	55.0	0	D
			11	16.0	120.	58.0	0	D
			12	26.8	135.	58.0	0	D
			13	20.0	140.	59.0	0	D
			14	8.8	-2.	62.0	0	C
			15	14.2	120.	68.0	0	D
			16	10.6	30.	62.0	0	C
			17	18.0	105.	74.0	0	D
			18	16.2	120.	72.0	0	D
			19	-1.0	-1.	-1.0	1	D
			20	-1.0	-1.	-1.0	1	D
			21	-1.0	-1.	-1.0	1	D
			22	-1.0	-1.	-1.0	0	D
			23	-1.0	-1.	-1.0	0	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
3	2	14	15	.0	0.	52.0	0	B
			16	4.6	330.	50.0	0	B
			17	.0	0.	48.0	0	D
			18	.0	0.	40.0	0	D
			19	.0	0.	43.0	0	D
			20	.0	0.	31.0	0	D
			21	.0	0.	32.0	0	D
			22	.0	0.	34.0	0	D
			23	.0	0.	33.0	0	D
		15	0	.0	0.	33.0	0	D
			1	.0	0.	29.0	0	D
			2	.0	0.	26.0	0	D
			3	.0	0.	30.0	0	D
			4	4.6	150.	31.0	0	D
			5	10.4	270.	32.0	0	D
			6	18.4	270.	42.0	1	D
			7	28.7	270.	42.0	1	D
			8	18.4	270.	35.0	0	D
			9	26.5	270.	38.0	0	D
			10	20.7	270.	38.0	0	D
			11	20.0	270.	40.0	0	D
			12	24.2	270.	42.0	0	D
			13	20.7	270.	42.0	0	D
			14	18.4	270.	42.0	0	D
			15	20.7	300.	45.0	0	C
			16	24.1	300.	45.0	0	C
			17	17.2	300.	42.0	0	D
			18	9.2	300.	39.0	0	E
			19	6.9	300.	35.0	0	E
			20	8.1	330.	33.0	0	E
			21	9.2	330.	32.0	0	E
			22	6.9	300.	32.0	0	E
			23	6.9	270.	30.0	0	E
		16	0	6.9	270.	30.0	0	E
			1	5.8	300.	29.0	0	F
			2	5.8	240.	27.0	0	F
			3	4.6	240.	27.0	0	F
			4	4.6	270.	25.0	0	F
			5	4.6	270.	25.0	0	F
			6	4.6	240.	24.0	0	F
			7	6.9	270.	27.0	0	B
			8	9.2	300.	27.0	0	B
			9	6.9	270.	29.0	0	B
			10	9.2	300.	33.0	0	B
			11	10.4	300.	36.0	0	B
			12	12.7	300.	39.0	0	C
			13	13.1	300.	41.0	0	C
			14	20.7	330.	42.0	0	C
			15	18.4	330.	42.0	0	C
			16	16.1	330.	41.0	0	D
			17	12.7	330.	39.0	0	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
3	2	16	18	9.2	330.	36.0	0	E
			19	10.3	300.	34.0	0	E
			20	9.2	300.	34.0	0	E
			21	13.8	330.	35.0	0	D
			22	13.8	330.	35.0	0	D
			23	8.1	270.	31.0	0	E
		17	0	10.4	300.	31.0	0	E
			1	11.5	300.	31.0	0	D
			2	10.4	300.	28.0	0	E
			3	11.5	300.	29.0	0	D
			4	11.5	300.	28.0	0	D
			5	15.0	300.	28.0	0	D
			6	16.1	300.	30.0	0	D
			7	34.5	300.	30.0	0	C
			8	12.7	300.	30.0	0	C
			9	13.8	330.	30.0	0	D
			10	20.7	330.	32.0	0	D
			11	27.6	330.	34.0	0	D
			12	19.6	330.	36.0	0	D
			13	19.6	360.	37.0	0	D
			14	23.0	330.	39.0	0	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
3	3	17	14	9.2	75.	-16.0	-2	C
			15	10.3	115.	-14.0	-2	C
			16	7.9	135.	-13.0	-2	C
			17	7.6	105.	-12.0	-2	C
			18	3.2	125.	-12.0	-2	D
			19	5.5	195.	-11.0	-2	D
			20	4.1	225.	-10.0	-2	D
			21	4.4	225.	-11.0	-2	D
			22	10.5	275.	-11.0	-2	D
			23	13.6	265.	-11.0	-2	D
		18	0	4.9	295.	-11.0	-2	D
			1	14.5	285.	-12.0	-2	D
			2	15.8	285.	-16.0	-2	D
			3	14.7	285.	-17.0	-2	D
			4	13.9	275.	-20.0	-2	D
			5	17.0	265.	-22.0	-2	D
			6	14.4	265.	-23.0	-2	D
			7	14.1	275.	-24.0	-2	D
			8	16.8	275.	-25.0	-2	D
			9	13.3	285.	-25.0	-2	D
			10	15.0	285.	-25.0	-2	D
			11	16.0	285.	-25.0	-2	D
			12	14.8	285.	-24.0	-2	C
			13	11.7	265.	-22.0	-2	C
			14	13.2	265.	-22.0	-2	C
			15	10.3	275.	-20.0	-2	C
			16	11.1	285.	-22.0	-2	C
			17	9.4	285.	-22.0	-2	D
			19	8.0	280.	-24.0	-2	E
			20	6.1	280.	-24.0	-2	F
			21	4.7	260.	-25.0	-2	F
			22	4.3	-2.	-25.0	-2	F
			23	4.0	-2.	-25.0	-2	F
		19	0	3.4	-2.	-25.0	-2	F
			1	2.2	-2.	-25.0	-2	F
			2	2.1	-2.	-25.0	-2	F
			3	1.1	-2.	-25.0	-2	F
			4	1.4	-2.	-25.0	-2	F
			5	1.0	-2.	-25.0	-2	F
			6	1.1	-2.	-25.0	-2	F
			7	1.2	-2.	-25.0	-2	F
			8	2.2	-2.	-25.0	-2	B
			9	2.7	-2.	-25.0	-2	B
			10	3.4	90.	-24.0	-2	B
			11	5.0	105.	-21.0	-2	C
			12	7.8	120.	-17.0	-2	B
			13	10.6	125.	-15.0	-2	C
			14	10.6	120.	-13.0	-2	C
			15	10.1	100.	-13.0	-2	C
			16	8.4	100.	-14.0	-2	E

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
3	3	19	17	4.5	120.	-17.0	-2	F
			18	8.5	120.	-20.0	-2	E
				10.7	125.	-18.0	-2	E
			20	8.5	105.	-21.0	-2	E
			21	7.0	115.	-22.0	-2	E
			22	6.1	-2.	-22.0	-2	F
			23	6.6	100.	-23.0	-2	F
		20	0	8.5	100.	-23.0	-2	E
			1	7.9	100.	-24.0	-2	E
			2	7.7	100.	-24.0	-2	E
			3	12.6	120.	-21.0	-2	D
			4	9.1	100.	-23.0	-2	E
			5	7.7	110.	-24.0	-2	E
			6	4.5	-2.	-24.0	-2	F
			7	8.1	120.	-23.0	-2	E
			8	8.3	135.	-24.0	-2	C
			9	9.4	120.	-21.0	-2	C
			10	12.6	120.	-19.0	-2	D
			11	12.2	135.	-16.0	-2	D
			12	9.2	145.	-12.0	-2	C
			13	9.5	150.	-10.0	-2	C
			14	10.4	125.	-9.0	-2	C
			15	12.1	135.	-8.0	-2	D
			16	14.0	150.	-8.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
4	1	21	16	7.6	-2.	70.0	0	B
			17	8.0	0.	70.0	0	B
			18	11.8	350.	69.0	0	B
			19	12.2	10.	65.0	0	C
			20	16.0	20.	61.0	1	D
			21	19.0	300.	49.0	1	D
			22	18.0	330.	49.0	1	D
			23	3.6	-2.	49.0	0	D
		22	0	2.7	-2.	48.0	0	D
			1	2.8	-2.	47.0	0	E
			2	1.2	-2.	46.0	0	E
			3	3.1	-2.	46.0	0	E
			4	3.2	-2.	49.0	0	E
			5	3.8	-2.	49.0	0	E
			6	4.0	-2.	49.0	0	B
			7	1.9	-2.	52.0	0	B
			8	3.0	180.	55.0	0	B
			9	4.8	210.	57.0	0	C
			10	7.5	240.	60.0	0	C
			11	10.5	270.	63.0	0	C
			12	11.3	255.	70.0	0	D
			13	13.0	270.	70.0	0	D
			14	15.0	270.	71.0	0	D
			15	15.6	270.	72.0	0	D
			16	12.7	270.	73.0	0	C
			17	11.8	315.	72.0	0	C
			18	9.2	315.	71.0	0	C
			19	7.6	330.	70.0	0	B
			20	6.0	360.	65.0	0	C
			21	8.2	60.	62.0	0	E
			22	10.1	60.	58.0	0	E
			23	11.0	60.	55.0	0	E
		23	0	11.6	60.	52.0	0	D
			1	11.8	60.	52.0	0	D
			2	13.5	60.	51.0	0	D
			3	12.5	60.	50.0	0	D
			4	11.0	60.	50.0	0	D
			5	3.7	-2.	51.0	0	E
			6	3.2	-2.	55.0	0	A
			7	6.7	45.	53.0	0	A
			8	4.5	-2.	62.0	0	A
			9	6.6	60.	65.0	0	A
			10	7.4	45.	68.0	0	A
			11	10.0	105.	72.0	0	A
			12	9.0	105.	77.0	0	B
			13	8.6	135.	80.0	0	B
			14	8.3	120.	82.0	0	C
			15	20.3	120.	71.0	0	D
			16	19.5	120.	72.0	0	D
			17	15.0	90.	68.0	0	D
			18	16.8	60.	65.0	0	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
4	1	23	19	15.0	80.	64.0	0	D
			20	16.0	70.	58.0	0	D
			21	11.5	75.	52.0	0	D
			22	14.3	60.	50.0	0	D
			23	14.5	75.	50.0	0	D
		24	0	15.0	90.	50.0	0	D
			1	14.0	90.	50.0	0	D
			2	16.0	90.	49.0	0	D
			3	14.8	90.	48.0	0	D
			4	4.5	90.	48.0	0	D
			5	11.8	90.	48.0	0	D
			6	2.8	90.	51.0	0	A
			7	2.7	-2.	61.0	0	A
			8	3.5	225.	65.0	0	A
			9	3.8	245.	72.0	0	A
			10	4.5	-2.	73.0	0	A
			11	5.0	-2.	78.0	0	A
			12	6.2	-2.	80.0	0	A
			13	7.5	-2.	78.0	0	B
			14	6.5	-2.	81.0	0	B
			15	6.2	-2.	78.0	0	B

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
4	2	1	0	5.6	-2.	12.0	-2	F
			1	6.7	285.	9.0	-2	E
			2	8.8	300.	11.0	-2	E
			3	6.2	300.	10.0	-2	F
			4	4.0	-2.	7.0	-2	F
			5	4.1	-2.	7.0	-2	F
			6	4.6	-2.	10.0	-2	F
			7	6.0	-2.	10.0	-2	F
			8	7.7	255.	11.0	-2	C
			9	7.8	250.	12.0	-2	C
			10	8.6	250.	16.0	-2	C
			11	12.9	260.	18.0	-2	D
			12	16.7	240.	18.0	-2	D
			13	16.5	240.	17.0	-2	D
			14	12.5	230.	16.0	-2	D
			15	8.1	235.	15.0	-2	C
			16	5.9	270.	11.0	-2	C
			17	5.2	270.	11.0	-2	C
			18	4.8	270.	11.0	-2	D
			19	6.3	235.	12.0	-2	D
			20	10.6	215.	14.0	-2	D
			21	13.4	215.	16.0	-2	D
			22	12.2	225.	18.0	-2	D
			23	14.1	225.	19.0	-2	D
		2	0	16.4	230.	20.0	-2	D
			1	16.5	230.	21.0	-2	D
			2	15.0	230.	22.0	-2	D
			3	13.5	230.	22.0	-2	D
			4	11.5	230.	22.0	-2	D
			5	13.3	240.	23.0	-2	D
			6	14.2	235.	25.0	-2	D
			7	11.8	240.	23.0	-2	D
			8	11.0	250.	26.0	-2	B
			9	7.1	265.	26.0	-2	B
			10	8.1	-2.	28.0	-2	B
			11	8.4	345.	24.0	-2	B
			12	6.0	-2.	24.0	-2	B
			13	4.5	-2.	23.0	-2	C
			14	5.9	70.	22.0	-2	C
			15	2.4	-2.	21.0	-2	B
			16	1.4	-2.	20.0	-2	B
			17	12.0	215.	29.0	-2	D
			18	15.4	210.	30.0	-2	D
			19	17.8	210.	30.0	-2	D
			20	20.0	220.	30.0	-2	D
			21	18.5	220.	31.0	-2	D
			22	17.9	215.	30.0	-2	D
			23	16.0	210.	29.0	-2	D
		3	0	13.6	-2.	29.0	-2	D
			1	14.1	230.	30.0	-2	D
			2	16.9	230.	32.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
4	2	3	3	13.3	215.	29.0	-2	D
			4	14.2	215.	30.0	-2	D
			5	13.8	270.	26.0	-2	D
			6	14.7	245.	30.0	-2	D
			7	8.9	-2.	26.0	-2	C
			8	8.2	270.	31.0	-2	C
			9	12.5	250.	33.0	-2	D
			10	14.2	240.	36.0	-2	D
			11	19.4	235.	40.0	-2	C
			12	18.6	230.	41.0	-2	D
			13	19.5	220.	42.0	-2	D
			14	14.7	210.	40.0	-2	D
			15	15.8	215.	40.0	-2	D
		30	17	5.3	275.	13.0	-2	B
			18	5.5	285.	10.0	-2	F
			19	1.5	-2.	7.0	-2	F
			20	5.0	305.	10.0	-2	F
			21	5.3	305.	10.0	-2	F
			22	5.6	315.	10.0	-2	F
			23	7.0	300.	15.0	-2	F

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
4	3	1	0	9.0	30.	-7.0	-2	D
			1	14.0	315.	-10.0	-2	D
			2	14.0	310.	-11.0	-2	D
			3	9.3	300.	-12.0	-2	D
			4	7.2	255.	-11.0	-2	D
			5	7.4	240.	-10.0	-2	D
			6	5.0	-2.	-12.0	-2	D
			7	11.6	270.	-5.0	-2	D
			8	9.6	270.	4.0	-2	C
			9	5.2	270.	6.0	-2	C
			10	6.7	285.	12.0	-2	C
			11	13.4	260.	15.0	-2	D
			12	10.6	240.	17.0	-2	D
			13	8.0	210.	17.0	-2	B
			14	5.1	-2.	16.0	-2	B
			15	2.4	-2.	16.0	-2	B
			16	2.0	-2.	13.0	-2	B
			17	4.7	285.	10.0	-2	E
			18	3.2	-2.	10.0	-2	F
			19	2.1	-2.	6.0	-2	F
			20	3.7	245.	6.0	-2	F
			21	3.0	240.	7.0	-2	F
			22	2.2	-2.	8.0	-2	F
			23	10.0	240.	12.0	-2	D
		2	0	11.4	240.	15.0	-2	D
			1	10.5	235.	15.0	-2	D
			2	16.2	210.	18.0	-2	D
			3	18.2	210.	19.0	-2	D
			4	17.0	210.	19.0	-2	D
			5	18.0	210.	20.0	-2	D
			6	10.9	210.	19.0	-2	D
			7	14.3	220.	19.0	-2	D
			8	22.9	225.	21.0	-2	D
			9	24.8	225.	21.0	-2	D
			10	22.1	225.	23.0	-2	D
			11	24.0	225.	24.0	-2	D
			12	20.5	230.	25.0	-2	D
			13	17.5	225.	26.0	-2	D
			14	19.7	240.	26.0	-2	D
			15	17.9	230.	25.0	-2	D
		30	15	10.8	270.	15.0	-2	C
			16	3.7	-2.	11.0	-2	E
			17	1.2	-2.	5.0	-2	F
			18	3.3	0.	3.0	-2	F
			19	3.9	15.	3.0	-2	F
			20	2.6	-2.	1.0	-2	F
			21	3.0	-2.	.0	-2	F
			22	4.6	30.	1.0	-2	F
			23	2.1	30.	2.0	-2	D
		31	0	2.0	-2.	2.0	-2	D
			1	2.4	30.	2.0	-2	D

MINE	VISIT	DAY	HOUR	Wind Speed m.p.h.	Wind Angle	Temp. °F	Precip. (inches)	Stability Class
4	3	31	2	2.0	-2.	7.0	-2	D
			3	2.5	-2.	10.0	-2	D
			4	1.3	-2.	10.0	-2	D
			5	1.9	-2.	8.0	-2	D
			6	11.8	240.	11.0	-2	D
			7	17.5	240.	12.0	-2	D
			8	20.5	225.	13.0	-2	D
			9	2.6	85.	.0	-2	D
			10	21.4	300.	5.0	-2	D
			11	23.2	320.	4.0	-2	D
			12	18.0	310.	5.0	-2	D
			13	12.0	305.	6.0	-2	C
			14	5.9	270.	10.0	-2	B
			15	5.3	315.	4.0	-2	C
			16	3.3	300.	2.0	-2	D
			17	6.1	15.	-2.0	-2	D
			18	6.0	30.	-3.0	-2	D
			19	8.2	30.	-5.0	-2	D
			20	10.8	45.	-7.0	-2	D
			21	7.6	45.	-7.0	-2	D
			22	6.5	60.	-8.0	-2	D
			23	7.0	60.	-8.0	-2	D

SOIL MOISTURE DATA

MINE	VISIT	SHIFT	DAY	HOUR	MIN	%Moisture by Weight	Cup Number
1	2	1	22	0	0	4.0	1
					10	2.8	32
					50	3.5	10
					55	3.2	22
			23	0	10	3.6	23
					20	3.3	29
					55	4.8	2
				1	0	3.7	1
			24	0	0	3.5	19
					30	4.4	8
				23	25	5.4	16
					35	5.5	6
		2	21	9	50	4.3	11
				11	45	6.3	29
				12	45	7.8	4
				13	0	5.3	25
			22	7	55	3.2	14
				8	10	2.4	6
					45	3.9	23
				10	15	2.7	24
			23	7	55	3.6	10
				8	5	7.5	27
					10	9.8	24
					45	4.2	20
		3	21	16	25	4.0	2
					35	5.3	26
				17	15	5.1	16
					25	3.6	20
			22	16	0	2.9	27
					10	5.6	28
					35	3.7	40
					45	3.5	19
			23	16	20	5.8	28
					30	9.9	14
				17	0	3.8	4
					10	3.8	26

```
                                    %Mois-
LISTING OF DATA BASE FOR FILE SOIL  ture by  Cup
MINE  VISIT  SHIFT  DA  HOUR  MIN   Weight  Number
----  -----  -----  --  ----  ---   -----   ---
 2     1      1     10    13   30      9.5    5
                               40     12.2    6
                               45      1.0    7
                    13    14   25     11.7    1
                    14     7   30     10.5    8
                               35      7.1    5
                               40     10.3    9
                           8   10      7.6   10
                          14   50     17.7   11
                    15     7   30     20.5   21
                           8   55     19.0   22
                           9    0     17.8   23
                               10     20.7   24
                               50     19.3   25
                    22     7    0     11.9   23
                           9   40      9.6   15
                          11   10      9.0   26
                               35      9.4   18
                    23     7   20      4.6   20
                               50      9.2   27
                           8   20      6.7    1
                               25      3.8   21
                          14   20      1.7    6
                               50      3.5    9
                    24     7   30      4.7   17
                           8   33      2.7   18
                               39      4.0    8
                               45      5.3   14
                          14   30      1.2   10
              2     11    16   15      6.0    8
                               55      3.6    9
                          17    0      4.9   10
                    13    15   10      8.1    2
                               20     11.8    3
                               25     12.2    4
                               50      5.3    5
                          22   40     14.8    3
                    14    15   30     19.9   12
                               40     18.3   13
                               45     17.1   14
                          16   20     12.6   15
                          21   55     20.6   16
                          22   35     17.4   17
                               50     15.9   18
                               55     18.2   19
                    15    15    0     13.7   26
                               45      6.7   27
                               50      7.7   28
                               55      6.9   29
                          16   45     10.6   30
                    22    15    0      5.7   12
```

LISTING OF DATA BASE FOR FILE SOIL

MINE	VISIT	SHIFT	DA	HOUR	MIN	%Moisture by Weight	Cup Number
2	1	2	22	15	30	2.2	17
				16	10	5.7	10
					30	3.1	25
					45	3.9	24
			23	15	25	8.6	3
					50	1.9	16
				16	0	3.3	31
				22	16	2.8	33
					45	3.4	35
			24	15	0	2.1	13
					35	7.1	23
				16	0	1.4	12
					10	2.6	15
		3	13	23	35	8.0	2
					40	9.3	4
					45	11.4	1
			14	0	15	8.6	7
				6	35	12.8	6
				23	35	18.2	20
			22	23	25	5.4	19
					40	1.5	22
			23	0	30	2.5	7
					45	5.5	2
					50	3.4	5
				6	45	5.5	11
				23	25	3.9	24
					55	2.4	30
			24	0	10	3.2	32
				6	55	3.7	26

```
                                         %Mois-
LISTING OF DATA BASE FOR FILE SOIL      ture by   Cup
MINE  VISIT  SHIFT     DA  HOUR   MIN   Weight   Number
----  ----   -----     --  ----   ---   -----    ---
   2      2      1     9     1    30     5.1    27
                                  40     6.6    50
                             2    20     3.6     4
                            23    55     5.0    16
                      10     0    55    10.9     5
                             1     0     5.0     1
                                   5     5.0    40
                            23    40     3.8     9
                      11     0    45     6.4    15
                                  50    -1.0    35
                                  55     3.7    14
                            23    35     5.9    17
                      12     0     0     1.5     8
                                   5     3.9    10
                                  10     3.1     9
                            23    40     5.0    28
                                  55     6.8     7
                 2     9     7    50     5.4    29
                             8    35     7.1    26
                             9    30     3.9     7
                                  45     7.9    22
                      10     9    55     3.7    32
                            10     0     8.8    23
                                   5    25.2     3
                                  10     2.6    30
                      11     7    35     4.4     2
                             8    50    13.1    12
                                  55     7.6    24
                             9     0    14.3    19
                                   5    -1.0    11
                 3     9    15     0     3.0     6
                                  15     4.9    34
                            17    10    16.3    18
                      10    14    45     8.9    10
                            16    45    -1.0    13
                                  50     4.0    21
                                  55     2.8    20
                      11    14    40     4.0    20
                            15    35     4.8    32
                                  40     6.9     5
                                  45     6.0    40
                                         3.1    34
```

```
                                                     %Mois-
LISTING OF DATA BASE FOR FILE      SOIL  ture by    Cup
MINE   VISIT  SHIFT   DA   HOUR    MIN   Weight    Number
----   ----   -----   --   ----    ---   -----      ---
 3      2      1       1    0       45    11.9        2
                                    50    14.5       28
                      15    0       20     4.4       27
                            1        5     3.1       40
                                    10     3.4        8
                                           4.5        4
                                    15     4.4       17
                           23       25     3.8        7
                      16    0       10     3.1        4
                                    15     4.6       17
                                    20    19.8       23
                           23        0     3.3       22
                                    40     4.3        7
                                    45     6.4       26
                      17    0        0     4.0       26
                                     5     8.3       22
                                    35     3.7       16
                                    40     4.0        1
                                    45     5.1       32
                           23       25     4.3        4
               2      15    6       40     6.7        9
                                    45     9.4        6
                                    48     7.5       34
                                    55     6.6       28
                            7        0    11.2        1
                                    10     6.4       14
                      16    7       30     4.1       32
                            8       10     5.1       10
                                    15     6.7        6
                                    40     3.8        5
                                    45    -1.0       11
                                    50     6.2        1
                      17    7        0     4.2       11
                                     5     3.6       10
                                    10     5.7       23
                                    13     5.1       24
                                    15      .7       29
                                    20     3.8       17
               3      14   15       20     4.5       12
                                    45     4.1       16
                           16       15     2.2       26
                                    20     3.1       29
                                    30     4.9       23
                                    35     9.8       24
                      15   15       10     4.0       21
                                    40     4.6       32
                           16        5     5.6       22
                                    10     5.9       19
                                    15     4.2       15
                                    20     5.0        5
                      16   15        5     3.5       14
```

```
                                                %Mois-
LISTING OF DATA BASE FOR FILE SOIL   ture by    Cup
 MINE  VISIT  SHIFT   DA   HOUR   MIN  Weight  Number
 ----  ----   -----   --   ----   ---  -----    ---
  3      2      3     16    16     0     4.8    24
                                   5     8.7    29
                                  35     2.3    34
                                  40     4.3    16
                                  45     7.3     8
                      17    -1    -1     4.4    14
                                         5.3     2
                                         4.5    20
                                         4.1     6
                                         3.8    25
                                         5.6     8
                      30    18    40    12.4    12
                                  50     5.6    50
                                  55     4.5     9
                            19     0     2.4    21
```

```
                                                     %Mois-
LISTING OF DATA BASE FOR FILE SOIL  ture by   Cup
 MINE  VISIT  SHIFT   DA  HOUR   MIN  Weight  Number
 ----  ----   -----   --  ----   ---  -----   ---
 4     1      1       22   7      0    9.8    23
                           9     40    9.6    15
                          11     10    9.0    26
                                 35    8.4    18
                      23   6     45    5.5    11
                           7     20    4.6    20
                                 50    9.2    27
                           8     20    6.7     1
                                 25    3.8    21
                      24   6     55    3.7    26
                           7     30    4.7    17
                           8     35    2.7    18
                                 40    4.0     8
                                 45    5.3    14
              2       22  15      0    5.7    12
                                 30    2.2    17
                          16     10    5.6    10
                                 30    5.6    25
                                 45    3.9    24
                      23  14     20    1.7     6
                                 50    3.5     9
                          15     25    8.6     3
                                 50    1.9    16
                          16      0    3.3    31
                      24  14     30    1.2    10
                          15      0    2.1    13
                                 35    7.1    23
                          16      0    1.4    12
                                 10    2.6    15
              3       22  23     25    5.4    19
                                 40    1.5    22
                      23   0     30    2.5     7
                                 45    5.5     2
                                 50    3.4     5
                          22     15    2.8    33
                                 25    8.7    34
                                 45    3.4    35
                          23     55    2.4    30
                      24   0     10    3.2    32
```

```
                                             %Mois-
LISTING OF DATA BASE FOR FILE SOIL   ture by    Cup
 MINE  VISIT  SHIFT   DA  HOUR  MIN   Weight   Number
 ----  ----   -----   --  ----  ---   -----    ---
  4     2      1       1    1   10    22.9      6
                                15     1.4     22
                       2    0    5     5.4     10
                                15    16.6      3
                                20     9.5     35
                            1    0     1.9     24
                       3    0   30     1.0      8
                           23   45     8.4     40
                                50     5.4      5
                                55     8.5     11
               2       2    7   35     9.7     26
                                40     9.7      4
                                45     7.2     34
                            8   10     1.0     27
                       3    5   40     1.2     20
                                43     5.9     23
                                45     2.0     14
                                50     9.1     91
               3       1   15   45     5.1     15
                                50    12.8     17
                                53    11.4     30
                           17   10     3.2      7
                       2   15   40    16.7     16
                                45     6.8     29
                                50     9.1     32
                           16   15     1.8     19
                       3   15   10     8.6     15
                                15    16.8     16
                           16   15      .6     12
                                45     3.6     19
```

ACTIVITY DATA

(See page 145 for explanation.)

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY HOUR  ACTIVC1 AREAC1 SEG1 QUANT1 ACTIVC2 AREAC2 SEG2 QUANT2 ACTIVC3 AREAC3 SEG3 QUANT3
---- ----- -----  --- ----  ------- ------ ---- ------ ------- ------ ---- ------ ------- ------ ---- ------
   1     1     1   24   16  DRAG    DRA       0   60.0 VEHI    ROA       0   20.0                      0     .0
                        17  DRAG    DRA       0   60.0 VEHI    ROA       0   20.0                      0     .0
                        18  DRAG    DRA       0   60.0 VEHI    ROA       0   10.0                      0     .0
                        19  DRAG    DRA       0   60.0 VEHI    ROA       0   10.0                      0     .0
                        20  DRAG    DRA       0   60.0 VEHI    ROA       0   10.0 VEHI    HAU       2    2.0
                        21  DRAG    DRA       0   60.0 VEHI    ROA       0   10.0                      0     .0
                        22  DRAG    DRA       0   60.0 VEHI    ROA       0    5.0                      0     .0
                        23  DRAG    DRA       0   60.0 VEHI    ROA       0    5.0                      0     .0
                   25    0  DRAG    DRA       0   60.0 VEHI    HAU       2    2.0                      0     .0
                         1  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         2  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         3  DRAG    DRA       0   60.0 VEHI    HAU       2    2.0                      0     .0
                         4  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         5  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         6  DRAG    DRA       0   60.0 VEHI    PUB       0    5.0                      0     .0
                         7  DRAG    DRA       0   60.0 VEHI    PUB       0   20.0 HAUL    HAU       0   24.0
                         8  HAUL    HAU       0   24.0 HAUL    HAU       2    6.0 LOAD    LOA       0  228.0
                         9  HAUL    HAU       0   26.0 HAUL    HAU       2    6.0 LOAD    LOA       0  247.0
                        10  HAUL    HAU       0   26.0 HAUL    HAU       2    6.0 LOAD    LOA       0  247.0
                        11  HAUL    HAU       0   26.0 HAUL    HAU       2   10.0 LOAD    LOA       0  247.0
                        12  HAUL    HAU       0   26.0 HAUL    HAU       2    6.0 LOAD    LOA       0  247.0
                        13  HAUL    HAU       0   24.0 HAUL    HAU       2    6.0 LOAD    LOA       0  228.0
                        14  HAUL    HAU       0   24.0 HAUL    HAU       2    6.0 LOAD    LOA       0  228.0
                        15  HAUL    HAU       2   10.0 VEHI    PUB       0   20.0 VEHI    HAU       1    4.0
                        16  DRAG    DRA       0   60.0 VEHI    PUB       0   20.0                      0     .0
                        17  DRAG    DRA       0   60.0 VEHI    PUB       0   20.0                      0     .0
                        18  DRAG    DRA       0   60.0 VEHI    PUB       0   10.0                      0     .0
                        19  DRAG    DRA       0   60.0 VEHI    PUB       0   10.0 VEHI    HAU       2    2.0
                        20  DRAG    DRA       0   60.0 VEHI    PUB       0   10.0                      0     .0
                        21  DRAG    DRA       0   60.0 VEHI    PUB       0   10.0                      0     .0
                        22  DRAG    DRA       0   60.0 VEHI    PUB       0    5.0                      0     .0
                        23  DRAG    DRA       0   60.0 VEHI    PUB       0    5.0                      0     .0
                   26    0  DRAG    DRA       0   60.0 VEHI    HAU       2    2.0                      0     .0
                         1  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         2  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         3  DRAG    DRA       0   60.0 VEHI    HAU       2    2.0                      0     .0
                         4  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         5  DRAG    DRA       0   60.0                   0     .0                      0     .0
                         6  DRAG    DRA       0   60.0 HAUL    PUB       0    5.0                      0     .0
                         7  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   26.0
                         8  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   28.0
                         9  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   26.0
                        10  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   26.0
                        11  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   26.0
                        12  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   26.0
                        13  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   28.0
                        14  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 HAUL    HAU       0   28.0
                        15  DRAG    DRA       0   60.0 HAUL    PUB       0   20.0 VEHI    HAU       4     .0
                        16  DRAG    DRA       0   60.0 VEHI    PUB       0   20.0                      0     .0
                        17  DRAG    DRA       0   60.0 VEHI    PUB       0   20.0                      0     .0
                        18  DRAG    DRA       0   60.0 VEHI    PUB       0   10.0                      0     .0
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT SHIFT DAY HOUR  ACTIVC1  AREAC1  SEG1  QUANT1 ACTIVC2  AREAC2  SEG2  QUANT2 ACTIVC3  AREAC3  SEG3  QUANT3
 ---- ----  ----- --- ----  -------  ------  ----  ------ -------  ------  ----  ------ -------  ------  ----  ------
 1     1     1    26   19   DRAG     DRA      0      60.0 VEHI     PUB      0      10.0 VEHI     HAU      2       2.0
                       20   DRAG     DRA      0      60.0 VEHI     PUB      0      10.0                   0        .0
                       21   DRAG     DRA      0      60.0 VEHI     PUB      0      10.0                   0        .0
                       22   DRAG     DRA      0      60.0 VEHI     PUB      0       5.0                   0        .0
                       23   DRAG     DRA      0      60.0 VEHI     PUB      0       5.0                   0        .0
                  27    0   DRAG     DRA      0      60.0 VEHI     HAU      2       2.0                   0        .0
                        1   DRAG     DRA      0      60.0                   0        .0                   0        .0
                        2   DRAG     DRA      0      60.0                   0        .0                   0        .0
                        3   DRAG     DRA      0      60.0 VEHI     HAU      2       2.0                   0        .0
                        4   DRAG     DRA      0      60.0                   0        .0                   0        .0
                        5   DRAG     DRA      0      60.0                   0        .0                   0        .0
                        6   DRAG     DRA      0      60.0 HAUL     PUB      0       5.0                   0        .0
                        7   DRAG     DRA      0      66.0 HAUL     PUB      0      20.0 HAUL     HAU      0      24.0
                        8   DRAG     DRA      0      60.0 HAUL     HAU      2       6.0 HAUL     HAU      0      24.0
                        9   DRAG     DRA      0      60.0 HAUL     HAU      2       6.0 HAUL     HAU      0      26.0
                       10   DRAG     DRA      0      60.0 HAUL     HAU      2       6.0 HAUL     HAU      0      26.0
                       11   DRAG     DRA      0      60.0 HAUL     HAU      2      10.0 HAUL     HAU      0      26.0
                       12   DRAG     DRA      0      60.0 HAUL     HAU      2       6.0 HAUL     HAU      0      26.0
                       13   DRAG     DRA      0      60.0 HAUL     HAU      2       6.0 HAUL     HAU      0      24.0
                       14   DRAG     DRA      0      60.0 HAUL     HAU      2       6.0 HAUL     HAU      0      24.0
                       15   DRAG     DRA      0      60.0 HAUL     HAU      2      10.0 VEHI     PUB      0      20.0
                       16   VEHI     PUB      0      20.0                   0        .0                   0        .0
                       17   VEHI     PUB      0      20.0                   0        .0                   0        .0
                       18   VEHI     PUB      0      10.0                   0        .0                   0        .0
                       19   VEHI     PUB      0      10.0 VEHI     HAU      2       2.0                   0        .0
                       20   VEHI     PUB      0      10.0                   0        .0                   0        .0
                       21   VEHI     PUB      0      10.0                   0        .0                   0        .0
                       22   VEHI     PUB      0       5.0                   0        .0                   0        .0
                       23   VEHI     PUB      0       5.0                   0        .0                   0        .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  1    2     1     21    7   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                         8   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                         9   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                        10   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                        11   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                        12   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                        13   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                        14   DRAG     DRA      0      45.0  HAUL     HAU      0       5.0  VEHI     HAU      0       7.5
                   22    7   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                         8   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                         9   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                        10   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                        11   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                        12   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                        13   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                        14   DRAG     DRA      0      60.0  HAUL     HAU      0      15.3  VEHI     HAU      0       8.1
                   23    7   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
                         8   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
                         9   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
                        10   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
                        11   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
                        12   BLAS     BLA      0     140.0                    0        .0                    0        .0

                        13   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
                        14   DRAG     DRA      0      60.0  HAUL     HAU      0      13.6  VEHI     HAU      0       8.8
             2     21   15   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        16   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        17   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        18   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        19   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        20   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        21   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        22   DRAG     DRA      0      60.0                    0        .0                    0        .0
                   22   15   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        16   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        17   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        18   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        19   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        20   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        21   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        22   DRAG     DRA      0      60.0                    0        .0                    0        .0
             3     22    0   DRAG     DRA      0      60.0                    0        .0                    0        .0
                         1   DRAG     DRA      0      60.0                    0        .0                    0        .0
                         2   DRAG     DRA      0      60.0                    0        .0                    0        .0
                         3   DRAG     DRA      0      60.0                    0        .0                    0        .0
                         4   DRAG     DRA      0      60.0                    0        .0                    0        .0
                         5   DRAG     DRA      0      60.0                    0        .0                    0        .0
                         6   DRAG     DRA      0      60.0                    0        .0                    0        .0
                        23   DRAG     DRA      0      60.0                    0        .0                    0        .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
1     3     1     19     7   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                         8   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                         9   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                        10   BLAS     BLA      1      14.0                     0        .0                    0        .0

                        11   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                        12   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                        13   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                        14   DRAG     DRA      0      60.0  HAUL     HAU      0       7.1  VEHI     HAU      0       7.5
                  20     1   BLAS     BLA      2     144.0                     0        .0                    0        .0
                         7   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                         8   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                         9   DRAG     DRA      0      50.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                        10   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                        11   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                        12   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                        13   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                        14   DRAG     DRA      0      60.0  HAUL     HAU      0      13.3  VEHI     HAU      0       7.5
                  21     7   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
                         8   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
                         9   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
                        10   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
                        11   BLAS     BLA      2      78.0                     0        .0                    0        .0

                        12   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
                        13   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
                        14   HAUL     HAU      0      10.5  VEHI     HAU      0       8.1  PUBL     PUB      0        .4
            2     19    15   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        16   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        17   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        18   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        19   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        20   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        21   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        22   DRAG     DRA      0      60.0                     0        .0                    0        .0
            3     19     0   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         1   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         2   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         3   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         4   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         5   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         6   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        23   DRAG     DRA      0      60.0                     0        .0                    0        .0
                  20     0   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         1   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         2   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         3   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         4   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         5   DRAG     DRA      0      60.0                     0        .0                    0        .0
                         6   DRAG     DRA      0      60.0                     0        .0                    0        .0
                        23   DRAG     DRA      0      60.0                     0        .0                    0        .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT  SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- -----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 2     1      1     8    23   VEHI     HAU      0     22.0                      0       .0                     0       .0
                    9     0   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          1   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          2   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          3   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          4   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          5   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          6   VEHI     HAU      0     22.0                      0       .0                     0       .0
                          7   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                          8   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                          9   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                         10   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                         11   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                         12   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                         13   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                         14   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     60      5.0
                         15   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         16   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         17   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         18   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         19   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         20   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         21   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         22   DRAG     DRA      1     15.0  DRAG     DRA      2     21.0  HAUL     HAU     50      4.0
                         23   GRAD     GRA      0     60.0  DRAG     DRA      1     13.0  DRAG     DRA      2     31.2
                   10     0   GRAD     GRA      0     60.0  DRAG     DRA      1     13.0  DRAG     DRA      2     31.2
                          1   GRAD     GRA      0     60.0  DRAG     DRA      1     13.0  DRAG     DRA      2     31.2
                          2   GRAD     GRA      0     60.0  DRAG     DRA      1     13.0  DRAG     DRA      2     31.2
                          3   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                          4   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                          5   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                          6   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                          7   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                          8   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                          9   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         10   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         11   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         12   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         13   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         14   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         15   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         16   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         17   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         18   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         19   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         20   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         21   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         22   SCRA     SCR      0     60.0  GRAD     GRA      0     60.0  DRAG     DRA      1     13.0
                         23   DRAG     DRA      1     10.0  DRAG     DRA      2     13.0  VEHI     HAU      0     22.0
                   11     0   DRAG     DRA      1     10.0  DRAG     DRA      2     13.0  VEHI     HAU      0     22.0
                          1   DRAG     DRA      1     10.0  DRAG     DRA      2     13.0  VEHI     HAU      0     22.0
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
 ----  ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 2      1      1    11     2   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           3   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           4   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           5   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           6   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           7   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           8   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                           9   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          10   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          11   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          12   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          13   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          14   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          15   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          16   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          17   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          18   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          19   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          20   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          21   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          22   DRAG     DRA       1     10.0  DRAG     DRA       2     13.0  VEHI     HAU       0     22.0
                          23   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                    12     0   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           1   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           2   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           3   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           4   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           5   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           6   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           7   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           8   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                           9   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          10   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          11   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                               DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          12   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          13   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          14   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          15   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          16   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          17   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          18   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          19   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          20   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          21   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          22   DRAG     DRA       1      3.0  DRAG     DRA       2      6.0  VEHI     HAU       0     22.0
                          23   DRAG     DRA       1     40.0  DRAG     DRA       2     20.0  VEHI     PUB       0     22.0
                    13     0   DRAG     DRA       1     40.0  DRAG     DRA       2     20.0  VEHI     PUB       0     22.0
                           1   DRAG     DRA       1     40.0  DRAG     DRA       2     20.0  VEHI     PUB       0     22.0
                           2   DRAG     DRA       1     40.0  DRAG     DRA       2     20.0  VEHI     PUB       0     22.0
                           3   DRAG     DRA       1     40.0  DRAG     DRA       2     20.0  VEHI     PUB       0     22.0
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT  SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
 ----  ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 2     1     1      13    4    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   VEHI     PUB      0     22.0
                          5    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   VEHI     PUB      0     22.0
                          6    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   VEHI     PUB      0     22.0
                          7    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                          8    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                          9    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         10    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         11    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         12    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         13    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         14    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         15    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         16    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         17    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         18    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         19    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         20    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         21    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
                         22    DRAG     DRA      1     40.0   DRAG     DRA      2     20.0   HAUL     HAU     50      3.9
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT DAY HOUR ACTIVC1 AREAC1 SEG1 QUANT1 ACTIVC2 AREAC2 SEG2 QUANT2 ACTIVC3 , AREAC3 SEG3 QUANT3
---- ----  ----- --- ---- ------- ------ ---- ------ ------- ------ ---- ------ -------   ------ ---- ------
 2    1     1    11    7  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                       8  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                       9  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                      10  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                      11  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                      12  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                      13  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                      14  DRAG    DRA     0     60.0 VEHI    HAU     0      2.5                     0      .0
                 12    7  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                       8  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                       9  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                      10  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                      11  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                      12  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                      13  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                      14  DRAG    DRA     0     56.8 VEHI    HAU     0      2.5                     0      .0
                 13    7  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                       8  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                       9  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                      10  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                      11  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                      12  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                      13  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
                      14  DRAG    DRA     0     55.6 VEHI    HAU     0      2.5                     0      .0
            2    11   15  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      16  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      17  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      18  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      19  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      20  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      21  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                      22  DRAG    DRA     0     51.0 HAUL    HAU     0      2.3 VEHI      HAU      0     5.0
                 12   15  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      16  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      17  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      18  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      19  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      20  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      21  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                      22  DRAG    DRA     0     52.6 VEHI    HAU     0      5.0                     0      .0
                 13   15  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      16  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      17  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      18  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      19  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      20  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      21  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
                      22  DRAG    DRA     0     46.6 VEHI    HAU     0      5.0                     0      .0
            3    11    0  DRAG    DRA     0     53.8 VEHI    HAU     0      2.5                     0      .0
                       1  DRAG    DRA     0     53.8 VEHI    HAU     0      2.5                     0      .0
                       2  DRAG    DRA     0     53.8 VEHI    HAU     0      2.5                     0      .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT DAY HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----- ----- --- ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 2     3     3    11    3   DRAG     DRA      0     53.8  VEHI     HAU      0      2.5                      0      .0
                        4   DRAG     DRA      0     53.8  VEHI     HAU      0      2.5                      0      .0
                        5   DRAG     DRA      0     53.8  VEHI     HAU      0      2.5                      0      .0
                        6   DRAG     DRA      0     53.8  VEHI     HAU      0      2.5                      0      .0
                       23   DRAG     DRA      0     53.8  VEHI     HAU      0      2.5                      0      .0
                  12    0   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                        1   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                        2   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                        3   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                        4   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                        5   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                        6   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                       23   DRAG     DRA      0     57.5  VEHI     HAU      0      2.5                      0      .0
                  13    0   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                        1   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                        2   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                        3   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                        4   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                        5   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                        6   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
                       23   DRAG     DRA      0     51.9  VEHI     HAU      0      2.5                      0      .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
3     3     1     11     7   HAUL     HAU      0        .6                     0      .0                     0      .0
                         8   HAUL     HAU      0        .6                     0      .0                     0      .0
                         9   HAUL     HAU      0        .6                     0      .0                     0      .0
                        10   HAUL     HAU      0        .6                     0      .0                     0      .0
                        11   HAUL     HAU      0        .6                     0      .0                     0      .0
                        12   HAUL     HAU      0        .6                     0      .0                     0      .0
                        13   HAUL     HAU      0        .6                     0      .0                     0      .0
                        14   HAUL     HAU      0        .6                     0      .0                     0      .0
                  12     7   HAUL     HAU      0       1.8                     0      .0                     0      .0
                         8   HAUL     HAU      0       1.8                     0      .0                     0      .0
                         9   HAUL     HAU      0       1.8                     0      .0                     0      .0
                        10   HAUL     HAU      0       1.8                     0      .0                     0      .0
                        11   HAUL     HAU      0       1.8                     0      .0                     0      .0
                        12   HAUL     HAU      0       1.8                     0      .0                     0      .0
                        13   HAUL     HAU      0       1.8                     0      .0                     0      .0
                        14   HAUL     HAU      0       1.8                     0      .0                     0      .0
                  17     8   BLAS     BLA      0     100.0                     0      .0                     0      .0
                  18     5   BLAS     BLA      0      50.0                     0      .0                     0      .0
                         7   VEHI     HAU      0       1.9                     0      .0                     0      .0
                         8   VEHI     HAU      0       1.9                     0      .0                     0      .0
                         9   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        10   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        11   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        12   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        13   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        14   VEHI     HAU      0       1.9                     0      .0                     0      .0
                  19     7   VEHI     HAU      0       1.9                     0      .0                     0      .0
                         8   VEHI     HAU      0       1.9                     0      .0                     0      .0
                         9   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        10   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        11   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        12   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        13   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        14   VEHI     HAU      0       1.9                     0      .0                     0      .0
                  20     7   VEHI     HAU      0       1.9                     0      .0                     0      .0
                         8   VEHI     HAU      0       1.9                     0      .0                     0      .0
                         9   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        10   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        11   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        12   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        13   VEHI     HAU      0       1.9                     0      .0                     0      .0
                        14   VEHI     HAU      0       1.9                     0      .0                     0      .0
            2     11    15   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        16   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        17   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        18   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        19   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        20   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        21   HAUL     HAU      0       3.3                     0      .0                     0      .0
                        22   HAUL     HAU      0       3.3                     0      .0                     0      .0
                  12    15   HAUL     HAU      0       3.6                     0      .0                     0      .0
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT  SHIFT  DAY  HOUR  ACTIVC1   AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
 ----  ----  -----  ---  ----  -------   ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 3     3     2      12   16    HAUL      HAU     0        3.6                    0        .0                     0       .0
                         17    HAUL      HAU     0        3.6                    0        .0                     0       .0
                         18    HAUL      HAU     0        3.6                    0        .0                     0       .0
                         19    HAUL      HAU     0        3.6                    0        .0                     0       .0
                         20    HAUL      HAU     0        3.6                    0        .0                     0       .0
                         21    HAUL      HAU     0        3.6                    0        .0                     0       .0
                         22    HAUL      HAU     0        3.6                    0        .0                     0       .0
                    13   15    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         16    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         17    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         18    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         19    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         20    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         21    HAUL      HAU     0        3.4                    0        .0                     0       .0
                         22    HAUL      HAU     0        3.4                    0        .0                     0       .0
                    17   15    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         16    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         17    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         18    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         19    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         20    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         21    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         22    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                    18   15    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         16    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         17    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         18    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         19    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         20    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         21    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                         22    HAUL      HAU     0        2.8  VEHI     HAU     0       3.8                     0       .0
                    19   15    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         16    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         17    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         18    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         19    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         20    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         21    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
                         22    HAUL      HAU     0        1.0  VEHI     HAU     0       3.8                     0       .0
             3      11    0    HAUL      HAU     0        4.1                    0        .0                     0       .0
                          1    HAUL      HAU     0        4.1                    0        .0                     0       .0
                          2    HAUL      HAU     0        4.1                    0        .0                     0       .0
                          3    HAUL      HAU     0        4.1                    0        .0                     0       .0
                          4    HAUL      HAU     0        4.1                    0        .0                     0       .0
                          5    HAUL      HAU     0        4.1                    0        .0                     0       .0
                          6    HAUL      HAU     0        4.1                    0        .0                     0       .0
                         23    HAUL      HAU     0        4.1                    0        .0                     0       .0
                    12    0    HAUL      HAU     0        1.5                    0        .0                     0       .0
                          1    HAUL      HAU     0        1.5                    0        .0                     0       .0
                          2    HAUL      HAU     0        1.5                    0        .0                     0       .0
                          3    HAUL      HAU     0        1.5                    0        .0                     0       .0
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT  SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
 ---- -----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
    3     3      3   12     4  HAUL     HAU        0     1.5                        0      .0                        0      .0
                            5  HAUL     HAU        0     1.5                        0      .0                        0      .0
                            6  HAUL     HAU        0     1.5                        0      .0                        0      .0
                           23  HAUL     HAU        0     1.5                        0      .0                        0      .0
                     13     0  HAUL     HAU        0     4.6                        0      .0                        0      .0
                            1  HAUL     HAU        0     4.6                        0      .0                        0      .0
                            2  HAUL     HAU        0     4.6                        0      .0                        0      .0
                            3  HAUL     HAU        0     4.6                        0      .0                        0      .0
                            4  HAUL     HAU        0     4.6                        0      .0                        0      .0
                            5  HAUL     HAU        0     4.6                        0      .0                        0      .0
                            6  HAUL     HAU        0     4.6                        0      .0                        0      .0
                           23  HAUL     HAU        0     3.6                        0      .0                        0      .0
                     18     0  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                            1  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                            2  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                            3  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                            4  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                            5  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                            6  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                           23  HAUL     HAU        0     3.9  VEHI     HAU        0     1.9                        0      .0
                     19     0  VEHI     HAU        0     1.9                        0      .0                        0      .0
                            1  VEHI     HAU        0     1.9                        0      .0                        0      .0
                            2  VEHI     HAU        0     1.9                        0      .0                        0      .0
                            3  VEHI     HAU        0     1.9                        0      .0                        0      .0
                            4  VEHI     HAU        0     1.9                        0      .0                        0      .0
                            5  VEHI     HAU        0     1.9                        0      .0                        0      .0
                            6  VEHI     HAU        0     1.9                        0      .0                        0      .0
                           23  VEHI     HAU        0     1.9                        0      .0                        0      .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----- -----  --- ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
   1     1     1    1    7  CDRL     CDL        0      .8                      0      .0                      0      .0

                         8  CDRL     CDL        0      .8                      0      .0                      0      .0

                         9  CDRL     CDL        0      .8                      0      .0                      0      .0

                        10  CDRL     CDL        0      .8                      0      .0                      0      .0

                        11  CDRL     CDL        0      .8                      0      .0                      0      .0

                        12  CDRL     CDL        0      .8                      0      .0                      0      .0

                        13  CDRL     CDL        0      .8                      0      .0                      0      .0

                        14  CDRL     CDL        0      .8                      0      .0                      0      .0

                    2    7  CDRL     CDL        0      .8                      0      .0                      0      .0

                         8  CDRL     CDL        0      .8                      0      .0                      0      .0

                         9  CDRL     CDL        0      .8                      0      .0                      0      .0

                        10  CDRL     CDL        0      .8                      0      .0                      0      .0

                        11  CDRL     CDL        0      .8                      0      .0                      0      .0

                        12  CDRL     CDL        0      .8                      0      .0                      0      .0

                        13  CDRL     CDL        0      .8                      0      .0                      0      .0

                        14  CDRL     CDL        0      .8                      0      .0                      0      .0

                   21    7  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                                     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                         8  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                         9  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                        10  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                        11  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                        12  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                        13  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                        14  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            DRAG     DRA        0    50.1  SCRA     GRA        0    90.0  GRAD     GRA        0     2.3
                        22  BLAS     DRA        0     8.0                      0      .0                      0      .0
                   22    7  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                            SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT DAY HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----  ----- --- ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
   4     1     1  22    8  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    30.0  GRAD     GRA        0     1.3                      0      .0
                        9  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
                       10  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
                       11  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
                       12  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
                       13  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
                       14  CDRL     CDL        0      .8  ODRL     ODL        0      .8                      0      .0
                           SCRA     GRA        0    90.0  GRAD     GRA        0     1.3                      0      .0
                  23    7  ODRL     ODL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                        8  ODRL     CDL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                        9  ODRL     CDL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    62.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                       10  ODRL     ODL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                       11  ODRL     CDL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                       12  ODRL     ODL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                       13  BIAS     CDL        0   116.0                      0      .0                      0      .0
                           ODRL     ODL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                       14  ODRL     ODL        0      .6                      0      .0                      0      .0
                           DRAG     DRA        0    52.5  SCRA     GRA        0   112.5  GRAD     GRA        0     1.1
                  24    7  CDRL     CDL        0      .6  ODRL     CDL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                        8  CDRL     CDL        0      .6  ODRL     CDL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                        9  CDRL     CDL        0      .6  ODRL     CDL        0      .8                      0      .0
                           DRAG     DRA        0    16.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                       10  CDRL     CDL        0      .6  ODRL     ODL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                       11  CDRL     CDL        0      .6  ODRL     CDL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                       12  CDRL     CDL        0      .6  ODRL     CDL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                       13  CDRL     CDL        0      .6  ODRL     ODL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                       14  CDRL     CDL        0      .6  ODRL     CDL        0      .8                      0      .0
                           DRAG     DRA        0    46.5  SCRA     GRA        0    90.0  GRAD     GRA        0      .6
                  30    7  CDRL     CDL        0      .3                      0      .0                      0      .0

                        8  CDRL     CDL        0      .3                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT  SHIFT  DAY  HOUR   ACTIVC1   AREAC1   SEG1   QUANT1  ACTIVC2   AREAC2   SEG2  QUANT2  ACTIVC3  AREAC3   SEG3   QUANT3
 ----  ----  -----  ---  ----   -------   ------   ----   ------  -------   ------   ----  ------  -------  ------   ----   ------
   4     1     1     30    9    CDRL      CDL       0        .3                       0       .0                       0         .0

                          10    CDRL      CDL       0        .3                       0       .0                       0         .0

                          11    CDRL      CDL       0        .3                       0       .0                       0         .0

                          12    CDRL      CDL       0        .3                       0       .0                       0         .0

                          13    CDRL      CDL       0        .3                       0       .0                       0         .0

                          14    CDRL      CDL       0        .3                       0       .0                       0         .0

                     31    7    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
                           8    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
                           9    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
                          10    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
                          11    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
                          12    CDRL      CDL       0        .8   ODRL      CDL       0       .8                       0         .0
                          13    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
                          14    CDRL      CDL       0        .8   ODRL      ODL       0       .8                       0         .0
               2     21   15    ODRL      ODL       0        .8                       0       .0                       0         .0

                          16    ODRL      CDL       0        .8                       0       .0                       0         .0

                          17    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      27.0   GRAD      GRA       0       .8  LOAD     LOA         0      459.0
                          18    ODRL      ODL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      27.0   GRAD      GRA       0       .8  LOAD     LOA         0      459.0
                          19    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      27.0   GRAD      GRA       0       .8  LOAD     LOA         0      459.0
                          20    ODRL      ODL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      27.0   GRAD      GRA       0       .8  LOAD     LOA         0      459.0
                          21    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      27.0   GRAD      GRA       0       .8  LOAD     LOA         0      459.0
                          22    ODRL      ODL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      27.0   GRAD      GRA       0       .8  LOAD     LOA         0      459.0
                     22   15    ODRL      ODL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          16    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          17    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          18    ODRL      ODL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          19    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          20    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          21    ODRL      CDL       0        .8                       0       .0                       0         .0
                                DRAG      DRA       0      45.7   GRAD      GRA       0       .5  LOAD     LOA         0      459.0
                          22    ODRL      CDL       0        .8                       0       .0                       0         .0
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
----  ----  ----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4     1     2    22   22   DRAG     DRA      0      45.7  GRAD     GRA      0       .5  LOAD     LOA      0    459.0
                   23   15   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        16   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        17   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        18   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        19   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        20   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        21   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                        22   ODRL     ODL      0        .8                   0       .0                    0       .0
                             DRAG     DRA      0      52.5  GRAD     GRA      0       .5  LOAD     LOA      0    612.0
                   24   15   ODRL     ODL      0        .8                   0       .0                    0       .0
                        16   ODRL     ODL      0        .8                   0       .0                    0       .0
                        17   ODRL     ODL      0        .8                   0       .0                    0       .0
                        18   ODRL     ODL      0        .8                   0       .0                    0       .0
                        19   ODRL     ODL      0        .8                   0       .0                    0       .0
                        20   ODRL     ODL      0        .8                   0       .0                    0       .0
                        21   ODRL     ODL      0        .8                   0       .0                    0       .0
                        22   ODRL     ODL      0        .8                   0       .0                    0       .0
              3    22    0   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                         1   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                         2   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                         3   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                         4   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                         5   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                         6   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                        23   DRAG     DRA      0      31.5  LOAD     LOA      0    306.0                    0       .0
                   23    0   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                         1   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                         2   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                         3   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                         4   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                         5   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                         6   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                        23   DRAG     DRA      0      51.0  GRAD     GRA      0       .5  LOAD     LOA      0    306.0
                   24    0   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                         1   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                         2   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                         3   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                         4   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                         5   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                         6   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
                        23   DRAG     DRA      0      51.0  SCRA     GRA      0     15.0  GRAD     GRA      0       .8
```

```
ACTIVITY DATA BASE - PART 1
 MINE VISIT SHIFT  DAY  HOUR   ACTIVC1   AREAC1   SEG1  QUANT1  ACTIVC2   AREAC2   SEG2  QUANT2  ACTIVC3   AREAC3   SEG3  QUANT3
 ---- ----  -----  ---  ----   -------   ------   ----  ------  -------   ------   ----  ------  -------   ------   ----  ------
   4    2     1      1     7   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                           8   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                           9   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                          10   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                          11   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                          12   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                          13   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                          14   DRAG      DRA         0    46.9  GRAD      GRA         0      .6  GRAD      DRA         0      .4
                     2     7   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                           8   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                           9   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                          10   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                          11   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                          12   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                          13   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                          14   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0      .5
                     3     7   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                           8   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                           9   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                          10   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                          11   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                          12   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                          13   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
                          14   DRAG      DRA         0    60.0  GRAD      GRA         0      .4  VEHI      HAU         0     5.0
              2      1    15   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          16   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          17   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          18   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          19   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          20   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          21   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                          22   DRAG      DRA         0    60.0  GRAD      GRA         0      .8  GRAD      DRA         0     1.0
                     2    15   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          16   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          17   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          18   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          19   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          20   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          21   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                          22   DRAG      DRA         0    60.0  HAUL      HAU        30     8.5  VEHI      HAU         0    18.8
                    30    15   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          16   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          17   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          18   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          19   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          20   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          21   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
                          22   DRAG      DRA         0    33.8  GRAD      DRA         0      .5  HAUL      HAU        30     5.8
              3      1     0   DRAG      DRA         0    60.0  HAUL      HAU        30    10.1  VEHI      HAU         0    12.5
                           1   DRAG      DRA         0    60.0  HAUL      HAU        30    10.1  VEHI      HAU         0    12.5
                           2   DRAG      DRA         0    60.0  HAUL      HAU        30    10.1  VEHI      HAU         0    12.5
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4    2     3     1     3   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         4   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         5   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         6   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                        23   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                   2     0   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         1   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         2   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         3   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         4   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         5   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                         6   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                        23   DRAG     DRA       0     60.0  HAUL     HAU      30     10.1  VEHI     HAU       0     12.5
                   3     0   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                         1   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                         2   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                         3   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                         4   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                         5   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                         6   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
                        23   DRAG     DRA       0     60.0  GRAD     GRA       0       .4  VEHI     HAU       0      2.5
```

```
ACTIVITY DATA BASE - PART 1
MINE VISIT SHIFT  DAY  HOUR  ACTIVC1  AREAC1  SEG1  QUANT1  ACTIVC2  AREAC2  SEG2  QUANT2  ACTIVC3  AREAC3  SEG3  QUANT3
---- ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 4     3     1     1     7   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                         8   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                         9   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                        10   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                        11   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                        12   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                        13   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                        14   DRAG     DRA       0    52.5   HAUL     HAU      30     8.5   VEHI     HAU       0    12.5
                   2     2   BLAS     BLA       0    36.0                      0      .0                       0      .0
                         7   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                         8   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                         9   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                        10   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                        11   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                        12   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                        13   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                        14   DRAG     DRA       0    15.0   HAUL     HAU      30     6.4   VEHI     HAU       0    12.5
                  31     1   BLAS     BLA       0    32.0                      0      .0                       0      .0
                         7   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                         8   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                         9   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                        10   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                        11   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                        12   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                        13   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
                        14   DRAG     DRA       0    52.5   HAUL     HAU      30     8.1   VEHI     HAU       0    12.5
             2     1    15   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        16   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        17   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        18   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        19   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        20   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        21   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                        22   DRAG     DRA       0    45.0   HAUL     HAU      30     8.4   VEHI     HAU       0    31.3
                   2    15   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        16   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        17   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        18   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        19   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        20   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        21   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                        22   HAUL     HAU      30      .8   HAUL     HAU      10     2.6   VEHI     HAU       0    31.3
                  31    15   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        16   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        17   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        18   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        19   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        20   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        21   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
                        22   DRAG     DRA       0    45.0   HAUL     HAU      30     5.5   HAUL     HAU      10     2.4
             3     1     0   DRAG     DRA       0    45.0   HAUL     HAU      30     7.9   VEHI     HAU       0    18.8
```

```
ACTIVITY DATA BASE - PART 1
 MINE  VISIT SHIFT  DAY  HOUR   ACTIVC1   AREAC1   SEG1   QUANT1  ACTIVC2   AREAC2  SEG2   QUANT2  ACTIVC3   AREAC3  SEG3   QUANT3
 ----  ----  -----  ---  ----   -------   ------   ----   ------  -------   ------  ----   ------  -------   ------  ----   ------
 4      3     3      1     1    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                           2    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                           3    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                           4    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                           5    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                           6    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                          23    DRAG      DRA       0      45.0   HAUL      HAU      30       7.9   VEHI      HAU       0      18.8
                    30     0    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                           1    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                           2    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                           3    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                           4    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                           5    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                           6    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                          23    DRAG      DRA       0      54.4   HAUL      HAU      30       7.4   VEHI      HAU       0      18.8
                    31     0    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                           1    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                           2    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                           3    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                           4    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                           5    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                           6    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
                          23    DRAG      DRA       0      15.0   GRAD      GRA       0        .8   HAUL      HAU      30      10.1
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
    1     1     1   24    16                      0      .0                      0      .0                      0      .0
                          17                      0      .0                      0      .0                      0      .0
                          18                      0      .0                      0      .0                      0      .0
                          19                      0      .0                      0      .0                      0      .0
                          20                      0      .0                      0      .0                      0      .0
                          21                      0      .0                      0      .0                      0      .0
                          22                      0      .0                      0      .0                      0      .0
                          23                      0      .0                      0      .0                      0      .0
                     25    0                      0      .0                      0      .0                      0      .0
                           1                      0      .0                      0      .0                      0      .0
                           2                      0      .0                      0      .0                      0      .0
                           3                      0      .0                      0      .0                      0      .0
                           4                      0      .0                      0      .0                      0      .0
                           5                      0      .0                      0      .0                      0      .0
                           6                      0      .0                      0      .0                      0      .0
                           7  LOAD     IOA        0   240.0  UNLD     UNL        0   240.0  VEHI     HAU        1     4.0
                           8  UNLD     UNL        0   228.0  VEHI     PUB        0    20.0  VEHI     IAU        1     4.0
                           9  UNLD     UNL        0   247.0  BLAS     BLA        0  9600.0  VEHI     PUB        0    20.0
                          10  UNLD     UNL        0   247.0  VEHI     PUB        0    20.0  VEHI     HAU        1     4.0
                          11  UNLD     UNL        0   247.0  VEHI     PUB        0    20.0  VEHI     HAU        1     6.0
                          12  UNLD     UNL        0   247.0  BLAS     BLA        0  4960.0  VEHI     PUB        0    20.0
                          13  UNLD     UNL        0   228.0  VEHI     PUB        0    20.0  VEHI     HAU        1     4.0
                          14  UNLD     UNL        0   228.0  VEHI     PUB        0    20.0  VEHI     HAU        1     4.0
                          15                      0      .0                      0      .0                      0      .0
                          16                      0      .0                      0      .0                      0      .0
                          17                      0      .0                      0      .0                      0      .0
                          18                      0      .0                      0      .0                      0      .0
                          19                      0      .0                      0      .0                      0      .0
                          20                      0      .0                      0      .0                      0      .0
                          21                      0      .0                      0      .0                      0      .0
                          22                      0      .0                      0      .0                      0      .0
                          23                      0      .0                      0      .0                      0      .0
                     26    0                      0      .0                      0      .0                      0      .0
                           1                      0      .0                      0      .0                      0      .0
                           2                      0      .0                      0      .0                      0      .0
                           3                      0      .0                      0      .0                      0      .0
                           4                      0      .0                      0      .0                      0      .0
                           5                      0      .0                      0      .0                      0      .0
                           6                      0      .0                      0      .0                      0      .0
                           7  LOAD     IOA        0   247.0  UNLD     UNL        0   247.0  VEHI     HAU        1     4.0
                           8  LOAD     IOA        0   266.0  UNLD     UNL        0   266.0  BLAS     BLA        0    56.0
                           9  LOAD     IOA        0   247.0  UNLD     UNL        0   247.0  VEHI     HAU        1     4.0
                          10  LOAD     IOA        0   247.0  UNLD     UNL        0   247.0  VEHI     HAU        1     4.0
                          11  LOAD     IOA        0   247.0  UNLD     UNL        0   247.0  VEHI     HAU        1     6.0
                          12  LOAD     IOA        0   247.0  UNLD     UNL        0   247.0  VEHI     HAU        1     4.0
                          13  LOAD     IOA        0   266.0  UNLD     UNL        0   266.0  VEHI     HAU        1     4.0
                          14  LOAD     IOA        0   266.0  UNLD     UNL        0   266.0  VEHI     HAU        1     4.0
                          15  VEHI     HAU        5      .0                      0      .0                      0      .0
                          16                      0      .0                      0      .0                      0      .0
                          17                      0      .0                      0      .0                      0      .0
                          18                      0      .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- ----- ----- ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
   1     1     1  26    19                   0         .0                   0         .0                   0         .0
                        20                   0         .0                   0         .0                   0         .0
                        21                   0         .0                   0         .0                   0         .0
                        22                   0         .0                   0         .0                   0         .0
                        23                   0         .0                   0         .0                   0         .0
                  27     0                   0         .0                   0         .0                   0         .0
                         1                   0         .0                   0         .0                   0         .0
                         2                   0         .0                   0         .0                   0         .0
                         3                   0         .0                   0         .0                   0         .0
                         4                   0         .0                   0         .0                   0         .0
                         5                   0         .0                   0         .0                   0         .0
                         6                   0         .0                   0         .0                   0         .0
                         7  LOAD     LOA     0      228.0  UNLD     UNL     0      228.0  VEHI     HAQ     1        4.0
                         8  LOAD     LOA     0      228.0  UNLD     UNL     0      228.0  VEHI     PUB     0       20.0
                         9  LOAD     LOA     0      247.0  UNLD     UNL     0      247.0  BLAS     BLA     0       54.0
                        10  LOAD     LOA     0      247.0  UNLD     UNL     0      247.0  VEHI     PUB     0       20.0
                        11  LOAD     LOA     0      247.0  UNLD     UNL     0      247.0  VEHI     PUB     0       20.0
                        12  LOAD     LOA     0      247.0  UNLD     UNL     0      247.0  VEHI     PUB     0       20.0
                        13  LOAD     LOA     0      228.0  UNLD     UNL     0      228.0  VEHI     PUB     0       20.0
                        14  LOAD     LOA     0      228.0  UNLD     UNL     0      228.0  VEHI     PUB     0       20.0
                        15  VEHI     HAU     1        4.0                   0         .0                   0         .0
                        16                   0         .0                   0         .0                   0         .0
                        17                   0         .0                   0         .0                   0         .0
                        18                   0         .0                   0         .0                   0         .0
                        19                   0         .0                   0         .0                   0         .0
                        20                   0         .0                   0         .0                   0         .0
                        21                   0         .0                   0         .0                   0         .0
                        22                   0         .0                   0         .0                   0         .0
                        23                   0         .0                   0         .0                   0         .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  1    2     1     21     7  PUBL     PUB        0      .4                      0      .0                      0      .0
                          8  PUBL     PUB        0      .4                      0      .0                      0      .0
                          9  PUBL     PUB        0      .4                      0      .0                      0      .0
                         10  PUBL     PUB        0      .4                      0      .0                      0      .0
                         11  PUBL     PUB        0      .4                      0      .0                      0      .0
                         12  PUBL     PUB        0      .4                      0      .0                      0      .0
                         13  PUBL     PUB        0      .4                      0      .0                      0      .0
                         14  PUBL     PUB        0      .4                      0      .0                      0      .0
                   22     7  PUBL     PUB        0      .4                      0      .0                      0      .0
                          8  PUBL     PUB        0      .4                      0      .0                      0      .0
                          9  PUBL     PUB        0      .4                      0      .0                      0      .0
                         10  PUBL     PUB        0      .4                      0      .0                      0      .0
                         11  PUBL     PUB        0      .4                      0      .0                      0      .0
                         12  PUBL     PUB        0      .4                      0      .0                      0      .0
                         13  PUBL     PUB        0      .4                      0      .0                      0      .0
                         14  PUBL     PUB        0      .4                      0      .0                      0      .0
                   23     7  PUBL     PUB        0      .4                      0      .0                      0      .0
                          8  PUBL     PUB        0      .4                      0      .0                      0      .0
                          9  PUBL     PUB        0      .4                      0      .0                      0      .0
                         10  PUBL     PUB        0      .4                      0      .0                      0      .0
                         11  PUBL     PUB        0      .4                      0      .0                      0      .0
                         12
                             PUBL     PUB        0      .4                      0      .0                      0      .0
                         13  PUBL     PUB        0      .4                      0      .0                      0      .0
                         14  PUBL     PUB        0      .4                      0      .0                      0      .0
                   21    15                      0      .0                      0      .0                      0      .0
                         16                      0      .0                      0      .0                      0      .0
                         17                      0      .0                      0      .0                      0      .0
                         18                      0      .0                      0      .0                      0      .0
                         19                      0      .0                      0      .0                      0      .0
                         20                      0      .0                      0      .0                      0      .0
                         21                      0      .0                      0      .0                      0      .0
                         22                      0      .0                      0      .0                      0      .0
                   22    15                      0      .0                      0      .0                      0      .0
                         16                      0      .0                      0      .0                      0      .0
                         17                      0      .0                      0      .0                      0      .0
                         18                      0      .0                      0      .0                      0      .0
                         19                      0      .0                      0      .0                      0      .0
                         20                      0      .0                      0      .0                      0      .0
                         21                      0      .0                      0      .0                      0      .0
                         22                      0      .0                      0      .0                      0      .0
             3     22     0                      0      .0                      0      .0                      0      .0
                          1                      0      .0                      0      .0                      0      .0
                          2                      0      .0                      0      .0                      0      .0
                          3                      0      .0                      0      .0                      0      .0
                          4                      0      .0                      0      .0                      0      .0
                          5                      0      .0                      0      .0                      0      .0
                          6                      0      .0                      0      .0                      0      .0
                         23                      0      .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ----  ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
   1     3     1     19    7   PUBL     PUB      0       .4                     0      .0                     0      .0
                           8   PUBL     PUB      0       .4                     0      .0                     0      .0
                           9   PUBL     PUB      0       .4                     0      .0                     0      .0
                          10                     0       .0                     0      .0                     0      .0
                               PUBL     PUB      0       .4                     0      .0                     0      .0
                          11   PUBL     PUB      0       .4                     0      .0                     0      .0
                          12   PUBL     PUB      0       .4                     0      .0                     0      .0
                          13   PUBL     PUB      0       .4                     0      .0                     0      .0
                          14   PUBL     PUB      0       .4                     0      .0                     0      .0
                     20    1                     0       .0                     0      .0                     0      .0
                           7   PUBL     PUB      0       .4                     0      .0                     0      .0
                           8   PUBL     PUB      0       .4                     0      .0                     0      .0
                           9   PUBL     PUB      0       .4                     0      .0                     0      .0
                          10   PUBL     PUB      0       .4                     0      .0                     0      .0
                          11   PUBL     PUB      0       .4                     0      .0                     0      .0
                          12   PUBL     PUB      0       .4                     0      .0                     0      .0
                          13   PUBL     PUB      0       .4                     0      .0                     0      .0
                          14   PUBL     PUB      0       .4                     0      .0                     0      .0
                     21    7                     0       .0                     0      .0                     0      .0
                           8                     0       .0                     0      .0                     0      .0
                           9                     0       .0                     0      .0                     0      .0
                          10                     0       .0                     0      .0                     0      .0
                          11                     0       .0                     0      .0                     0      .0

                          12                     0       .0                     0      .0                     0      .0
                          13                     0       .0                     0      .0                     0      .0
                          14                     0       .0                     0      .0                     0      .0
               2     19   15                     0       .0                     0      .0                     0      .0
                          16                     0       .0                     0      .0                     0      .0
                          17                     0       .0                     0      .0                     0      .0
                          18                     0       .0                     0      .0                     0      .0
                          19                     0       .0                     0      .0                     0      .0
                          20                     0       .0                     0      .0                     0      .0
                          21                     0       .0                     0      .0                     0      .0
                          22                     0       .0                     0      .0                     0      .0
               3     19    0                     0       .0                     0      .0                     0      .0
                           1                     0       .0                     0      .0                     0      .0
                           2                     0       .0                     0      .0                     0      .0
                           3                     0       .0                     0      .0                     0      .0
                           4                     0       .0                     0      .0                     0      .0
                           5                     0       .0                     0      .0                     0      .0
                           6                     0       .0                     0      .0                     0      .0
                          23                     0       .0                     0      .0                     0      .0
                     20    0                     0       .0                     0      .0                     0      .0
                           1                     0       .0                     0      .0                     0      .0
                           2                     0       .0                     0      .0                     0      .0
                           3                     0       .0                     0      .0                     0      .0
                           4                     0       .0                     0      .0                     0      .0
                           5                     0       .0                     0      .0                     0      .0
                           6                     0       .0                     0      .0                     0      .0
                          23                     0       .0                     0      .0                     0      .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT DAY HOUR   ACTIVC4   AREAC4   SEG4   QUANT4   ACTIVC5   AREAC5   SEG5   QUANT5   ACTIVC6   AREAC6   SEG6   QUANT6
---- ----- ----- --- ----   -------   ------   ----   ------   -------   ------   ----   ------   -------   ------   ----   ------
   2     1     1   8   23                         0       .0                         0       .0                         0       .0
                   9    0                         0       .0                         0       .0                         0       .0
                        1                         0       .0                         0       .0                         0       .0
                        2                         0       .0                         0       .0                         0       .0
                        3                         0       .0                         0       .0                         0       .0
                        4                         0       .0                         0       .0                         0       .0
                        5                         0       .0                         0       .0                         0       .0
                        6                         0       .0                         0       .0                         0       .0
                        7   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOA       LOA         2    765.0
                        8   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                        9   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                       10   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                       11   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                       12   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                       13   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                       14   HAUL      HAU        50      3.0   LOAD      LOA         1    446.0   LOAD      LOA         2    765.0
                       15   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       16   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       17   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       18   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       19   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       20   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       21   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       22   LOAD      LOA         1    575.0   UNLD      TPL         0    900.0   VEHI      HAU         0     49.0
                       23                         0       .0                         0       .0                         0       .0
                  10    0                         0       .0                         0       .0                         0       .0
                        1                         0       .0                         0       .0                         0       .0
                        2                         0       .0                         0       .0                         0       .0
                        3   DRAG      DRA         2     31.2                         0       .0                         0       .0
                        4   DRAG      DRA         2     31.2                         0       .0                         0       .0
                        5   DRAG      DRA         2     31.2                         0       .0                         0       .0
                        6   DRAG      DRA         2     31.2                         0       .0                         0       .0
                        7   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                        8   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                        9   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       10   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       11   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       12   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       13   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       14   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       15   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       16   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       17   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       18   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       19   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       20   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       21   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       22   DRAG      DRA         2     31.2   HAUL      HAU        50      4.1   HAUL      HAU        60      2.2
                       23                         0       .0                         0       .0                         0       .0
                  11    0                         0       .0                         0       .0                         0       .0
                        1                         0       .0                         0       .0                         0       .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
    2     1     1   11     2                      0      .0                      0      .0                      0      .0
                           3                      0      .0                      0      .0                      0      .0
                           4                      0      .0                      0      .0                      0      .0
                           5                      0      .0                      0      .0                      0      .0
                           6                      0      .0                      0      .0                      0      .0
                           7                      0      .0                      0      .0                      0      .0
                           8                      0      .0                      0      .0                      0      .0
                           9                      0      .0                      0      .0                      0      .0
                          10                      0      .0                      0      .0                      0      .0
                          11                      0      .0                      0      .0                      0      .0
                          12                      0      .0                      0      .0                      0      .0
                          13                      0      .0                      0      .0                      0      .0
                          14                      0      .0                      0      .0                      0      .0
                          15                      0      .0                      0      .0                      0      .0
                          16                      0      .0                      0      .0                      0      .0
                          17                      0      .0                      0      .0                      0      .0
                          18                      0      .0                      0      .0                      0      .0
                          19                      0      .0                      0      .0                      0      .0
                          20                      0      .0                      0      .0                      0      .0
                          21                      0      .0                      0      .0                      0      .0
                          22                      0      .0                      0      .0                      0      .0
                          23                      0      .0                      0      .0                      0      .0
                    12     0                      0      .0                      0      .0                      0      .0
                           1                      0      .0                      0      .0                      0      .0
                           2                      0      .0                      0      .0                      0      .0
                           3                      0      .0                      0      .0                      0      .0
                           4                      0      .0                      0      .0                      0      .0
                           5                      0      .0                      0      .0                      0      .0
                           6                      0      .0                      0      .0                      0      .0
                           7                      0      .0                      0      .0                      0      .0
                           8                      0      .0                      0      .0                      0      .0
                           9                      0      .0                      0      .0                      0      .0
                          10                      0      .0                      0      .0                      0      .0
                          11                      0      .0                      0      .0                      0      .0

                          12                      0      .0                      0      .0                      0      .0
                          13                      0      .0                      0      .0                      0      .0
                          14                      0      .0                      0      .0                      0      .0
                          15                      0      .0                      0      .0                      0      .0
                          16                      0      .0                      0      .0                      0      .0
                          17                      0      .0                      0      .0                      0      .0
                          18                      0      .0                      0      .0                      0      .0
                          19                      0      .0                      0      .0                      0      .0
                          20                      0      .0                      0      .0                      0      .0
                          21                      0      .0                      0      .0                      0      .0
                          22                      0      .0                      0      .0                      0      .0
                          23                      0      .0                      0      .0                      0      .0
                    13     0                      0      .0                      0      .0                      0      .0
                           1                      0      .0                      0      .0                      0      .0
                           2                      0      .0                      0      .0                      0      .0
                           3                      0      .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT  DAY HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- ----- -----  --- ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 1     1     1    13    4                       0      .0                       0      .0                       0      .0
                        5                       0      .0                       0      .0                       0      .0
                        6                       0      .0                       0      .0                       0      .0
                        7   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                        8   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                        9   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       10   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       11   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       12   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       13   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       14   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       15   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       16   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       17   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       18   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       19   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       20   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       21   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
                       22   HAUL     HAU       60     2.3   LOAD     LOA        1   671.5   LOAD     LOA        2   397.0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT DAY HOUR ACTIVC4 AREAC4 SEG4 QUANT4 ACTIVC5 AREAC5 SEG5 QUANT5 ACTIVC6 AREAC6 SEG6 QUANT6
---- ----- ----- --- ---- ------- ------ ---- ------ ------- ------ ---- ------ ------- ------ ---- ------
  2    3     1   11    7                    0     .0                    0     .0                    0     .0
                       8                    0     .0                    0     .0                    0     .0
                       9                    0     .0                    0     .0                    0     .0
                      10                    0     .0                    0     .0                    0     .0
                      11                    0     .0                    0     .0                    0     .0
                      12                    0     .0                    0     .0                    0     .0
                      13                    0     .0                    0     .0                    0     .0
                      14                    0     .0                    0     .0                    0     .0
                 12    7                    0     .0                    0     .0                    0     .0
                       8                    0     .0                    0     .0                    0     .0
                       9                    0     .0                    0     .0                    0     .0
                      10                    0     .0                    0     .0                    0     .0
                      11                    0     .0                    0     .0                    0     .0
                      12                    0     .0                    0     .0                    0     .0
                      13                    0     .0                    0     .0                    0     .0
                      14                    0     .0                    0     .0                    0     .0
                 13    7                    0     .0                    0     .0                    0     .0
                       6                    0     .0                    0     .0                    0     .0
                       9                    0     .0                    0     .0                    0     .0
                      10                    0     .0                    0     .0                    0     .0
                      11                    0     .0                    0     .0                    0     .0
                      12                    0     .0                    0     .0                    0     .0
                      13                    0     .0                    0     .0                    0     .0
                      14                    0     .0                    0     .0                    0     .0
             2   11   15                    0     .0                    0     .0                    0     .0
                      16                    0     .0                    0     .0                    0     .0
                      17                    0     .0                    0     .0                    0     .0
                      18                    0     .0                    0     .0                    0     .0
                      19                    0     .0                    0     .0                    0     .0
                      20                    0     .0                    0     .0                    0     .0
                      21                    0     .0                    0     .0                    0     .0
                      22                    0     .0                    0     .0                    0     .0
                 12   15                    0     .0                    0     .0                    0     .0
                      16                    0     .0                    0     .0                    0     .0
                      17                    0     .0                    0     .0                    0     .0
                      18                    0     .0                    0     .0                    0     .0
                      19                    0     .0                    0     .0                    0     .0
                      20                    0     .0                    0     .0                    0     .0
                      21                    0     .0                    0     .0                    0     .0
                      22                    0     .0                    0     .0                    0     .0
                 13   15                    0     .0                    0     .0                    0     .0
                      16                    0     .0                    0     .0                    0     .0
                      17                    0     .0                    0     .0                    0     .0
                      18                    0     .0                    0     .0                    0     .0
                      19                    0     .0                    0     .0                    0     .0
                      20                    0     .0                    0     .0                    0     .0
                      21                    0     .0                    0     .0                    0     .0
                      22                    0     .0                    0     .0                    0     .0
             3   11    0                    0     .0                    0     .0                    0     .0
                       1                    0     .0                    0     .0                    0     .0
                       2                    0     .0                    0     .0                    0     .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ----  ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  2     3     3     11     3                      0      .0                       0      .0                       0      .0
                           4                      0      .0                       0      .0                       0      .0
                           5                      0      .0                       0      .0                       0      .0
                           6                      0      .0                       0      .0                       0      .0
                          23                      0      .0                       0      .0                       0      .0
                    12     0                      0      .0                       0      .0                       0      .0
                           1                      0      .0                       0      .0                       0      .0
                           2                      0      .0                       0      .0                       0      .0
                           3                      0      .0                       0      .0                       0      .0
                           4                      0      .0                       0      .0                       0      .0
                           5                      0      .0                       0      .0                       0      .0
                           6                      0      .0                       0      .0                       0      .0
                          23                      0      .0                       0      .0                       0      .0
                    13     0                      0      .0                       0      .0                       0      .0
                           1                      0      .0                       0      .0                       0      .0
                           2                      0      .0                       0      .0                       0      .0
                           3                      0      .0                       0      .0                       0      .0
                           4                      0      .0                       0      .0                       0      .0
                           5                      0      .0                       0      .0                       0      .0
                           6                      0      .0                       0      .0                       0      .0
                          23                      0      .0                       0      .0                       0      .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT  SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- -----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 3    3      1     11     7                      0       .0                      0      .0                      0      .0
                          8                      0       .0                      0      .0                      0      .0
                          9                      0       .0                      0      .0                      0      .0
                         10                      0       .0                      0      .0                      0      .0
                         11                      0       .0                      0      .0                      0      .0
                         12                      0       .0                      0      .0                      0      .0
                         13                      0       .0                      0      .0                      0      .0
                         14                      0       .0                      0      .0                      0      .0
                   12     7                      0       .0                      0      .0                      0      .0
                          8                      0       .0                      0      .0                      0      .0
                          9                      0       .0                      0      .0                      0      .0
                         10                      0       .0                      0      .0                      0      .0
                         11                      0       .0                      0      .0                      0      .0
                         12                      0       .0                      0      .0                      0      .0
                         13                      0       .0                      0      .0                      0      .0
                         14                      0       .0                      0      .0                      0      .0
                   17     8                      0       .0                      0      .0                      0      .0
                   18     5                      0       .0                      0      .0                      0      .0
                          7                      0       .0                      0      .0                      0      .0
                          8                      0       .0                      0      .0                      0      .0
                          9                      0       .0                      0      .0                      0      .0
                         10                      0       .0                      0      .0                      0      .0
                         11                      0       .0                      0      .0                      0      .0
                         12                      0       .0                      0      .0                      0      .0
                         13                      0       .0                      0      .0                      0      .0
                         14                      0       .0                      0      .0                      0      .0
                   19     7                      0       .0                      0      .0                      0      .0
                          8                      0       .0                      0      .0                      0      .0
                          9                      0       .0                      0      .0                      0      .0
                         10                      0       .0                      0      .0                      0      .0
                         11                      0       .0                      0      .0                      0      .0
                         12                      0       .0                      0      .0                      0      .0
                         13                      0       .0                      0      .0                      0      .0
                         14                      0       .0                      0      .0                      0      .0
                   20     7                      0       .0                      0      .0                      0      .0
                          8                      0       .0                      0      .0                      0      .0
                          9                      0       .0                      0      .0                      0      .0
                         10                      0       .0                      0      .0                      0      .0
                         11                      0       .0                      0      .0                      0      .0
                         12                      0       .0                      0      .0                      0      .0
                         13                      0       .0                      0      .0                      0      .0
                         14                      0       .0                      0      .0                      0      .0
             2     11    15                      0       .0                      0      .0                      0      .0
                         16                      0       .0                      0      .0                      0      .0
                         17                      0       .0                      0      .0                      0      .0
                         18                      0       .0                      0      .0                      0      .0
                         19                      0       .0                      0      .0                      0      .0
                         20                      0       .0                      0      .0                      0      .0
                         21                      0       .0                      0      .0                      0      .0
                         22                      0       .0                      0      .0                      0      .0
                   12    15                      0       .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT  SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ----  ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  3     3      2     12    16                      0      .0                      0      .0                      0      .0
                           17                      0      .0                      0      .0                      0      .0
                           18                      0      .0                      0      .0                      0      .0
                           19                      0      .0                      0      .0                      0      .0
                           20                      0      .0                      0      .0                      0      .0
                           21                      0      .0                      0      .0                      0      .0
                           22                      0      .0                      0      .0                      0      .0
                     13    15                      0      .0                      0      .0                      0      .0
                           16                      0      .0                      0      .0                      0      .0
                           17                      0      .0                      0      .0                      0      .0
                           18                      0      .0                      0      .0                      0      .0
                           19                      0      .0                      0      .0                      0      .0
                           20                      0      .0                      0      .0                      0      .0
                           21                      0      .0                      0      .0                      0      .0
                           22                      0      .0                      0      .0                      0      .0
                     17    15                      0      .0                      0      .0                      0      .0
                           16                      0      .0                      0      .0                      0      .0
                           17                      0      .0                      0      .0                      0      .0
                           18                      0      .0                      0      .0                      0      .0
                           19                      0      .0                      0      .0                      0      .0
                           20                      0      .0                      0      .0                      0      .0
                           21                      0      .0                      0      .0                      0      .0
                           22                      0      .0                      0      .0                      0      .0
                     18    15                      0      .0                      0      .0                      0      .0
                           16                      0      .0                      0      .0                      0      .0
                           17                      0      .0                      0      .0                      0      .0
                           18                      0      .0                      0      .0                      0      .0
                           19                      0      .0                      0      .0                      0      .0
                           20                      0      .0                      0      .0                      0      .0
                           21                      0      .0                      0      .0                      0      .0
                           22                      0      .0                      0      .0                      0      .0
                     19    15                      0      .0                      0      .0                      0      .0
                           16                      0      .0                      0      .0                      0      .0
                           17                      0      .0                      0      .0                      0      .0
                           18                      0      .0                      0      .0                      0      .0
                           19                      0      .0                      0      .0                      0      .0
                           20                      0      .0                      0      .0                      0      .0
                           21                      0      .0                      0      .0                      0      .0
                           22                      0      .0                      0      .0                      0      .0
               3     11     0                      0      .0                      0      .0                      0      .0
                            1                      0      .0                      0      .0                      0      .0
                            2                      0      .0                      0      .0                      0      .0
                            3                      0      .0                      0      .0                      0      .0
                            4                      0      .0                      0      .0                      0      .0
                            5                      0      .0                      0      .0                      0      .0
                            6                      0      .0                      0      .0                      0      .0
                           23                      0      .0                      0      .0                      0      .0
                     12     0                      0      .0                      0      .0                      0      .0
                            1                      0      .0                      0      .0                      0      .0
                            2                      0      .0                      0      .0                      0      .0
                            3                      0      .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT  SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ----  ----  -- --  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 3     3     3      12     4                        0      .0                        0      .0                        0      .0
                           5                        0      .0                        0      .0                        0      .0
                           6                        0      .0                        0      .0                        0      .0
                          23                        0      .0                        0      .0                        0      .0
                    13     0                        0      .0                        0      .0                        0      .0
                           1                        0      .0                        0      .0                        0      .0
                           2                        0      .0                        0      .0                        0      .0
                           3                        0      .0                        0      .0                        0      .0
                           4                        0      .0                        0      .0                        0      .0
                           5                        0      .0                        0      .0                        0      .0
                           6                        0      .0                        0      .0                        0      .0
                          23                        0      .0                        0      .0                        0      .0
                    18     0                        0      .0                        0      .0                        0      .0
                           1                        0      .0                        0      .0                        0      .0
                           2                        0      .0                        0      .0                        0      .0
                           3                        0      .0                        0      .0                        0      .0
                           4                        0      .0                        0      .0                        0      .0
                           5                        0      .0                        0      .0                        0      .0
                           6                        0      .0                        0      .0                        0      .0
                          23                        0      .0                        0      .0                        0      .0
                    19     0                        0      .0                        0      .0                        0      .0
                           1                        0      .0                        0      .0                        0      .0
                           2                        0      .0                        0      .0                        0      .0
                           3                        0      .0                        0      .0                        0      .0
                           4                        0      .0                        0      .0                        0      .0
                           5                        0      .0                        0      .0                        0      .0
                           6                        0      .0                        0      .0                        0      .0
                          23                        0      .0                        0      .0                        0      .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT DAY HOUR  ACTIVC4 AREAC4 SEG4 QUANT4 ACTIVC5 AREAC5 SEG5 QUANT5 ACTIVC6 AREAC6 SEG6 QUANT6
 ---- ----- ----- --- ----  ------- ------ ---- ------ ------- ------ ---- ------ ------- ------ ---- ------
    4     1     1   T    7                  0       .0                 0       .0                 0       .0
                         8                  0       .0                 0       .0                 0       .0
                         9                  0       .0                 0       .0                 0       .0
                        10                  0       .0                 0       .0                 0       .0
                        11                  0       .0                 0       .0                 0       .0
                        12                  0       .0                 0       .0                 0       .0
                        13                  0       .0                 0       .0                 0       .0
                        14                  0       .0                 0       .0                 0       .0
                    2    7                  0       .0                 0       .0                 0       .0
                         8                  0       .0                 0       .0                 0       .0
                         9                  0       .0                 0       .0                 0       .0
                        10                  0       .0                 0       .0                 0       .0
                        11                  0       .0                 0       .0                 0       .0
                        12                  0       .0                 0       .0                 0       .0
                        13                  0       .0                 0       .0                 0       .0
                        14                  0       .0                 0       .0                 0       .0
                   2|1   7                  0       .0                 0       .0                 0       .0
                         8                  0       .0                 0       .0                 0       .0
                         9                  0       .0                 0       .0                 0       .0
                        10                  0       .0                 0       .0                 0       .0
                        11                  0       .0                 0       .0                 0       .0
                        12                  0       .0                 0       .0                 0       .0
                        13                  0       .0                 0       .0                 0       .0
                        14                  0       .0                 0       .0                 0       .0
                        22                  0       .0                 0       .0                 0       .0
                   22    7                  0       .0                 0       .0                 0       .0
                                            0       .0                 0       .0                 0       .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE  VISIT  SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ----  -----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
 4      1      1     22    8                      0       .0                      0      .0                      0      .0
                           9                      0       .0                      0      .0                      0      .0
                          10                      0       .0                      0      .0                      0      .0
                          11                      0       .0                      0      .0                      0      .0
                          12                      0       .0                      0      .0                      0      .0
                          13                      0       .0                      0      .0                      0      .0
                          14                      0       .0                      0      .0                      0      .0
                     23    7                      0       .0                      0      .0                      0      .0
                           8                      0       .0                      0      .0                      0      .0
                           9                      0       .0                      0      .0                      0      .0
                          10                      0       .0                      0      .0                      0      .0
                          11                      0       .0                      0      .0                      0      .0
                          12                      0       .0                      0      .0                      0      .0
                          13                      0       .0                      0      .0                      0      .0

                          14                      0       .0                      0      .0                      0      .0
                     24    7                      0       .0                      0      .0                      0      .0
                           8                      0       .0                      0      .0                      0      .0
                           9                      0       .0                      0      .0                      0      .0
                          10                      0       .0                      0      .0                      0      .0
                          11                      0       .0                      0      .0                      0      .0
                          12                      0       .0                      0      .0                      0      .0
                          13                      0       .0                      0      .0                      0      .0
                          14                      0       .0                      0      .0                      0      .0
                     30    7                      0       .0                      0      .0                      0      .0
                           8                      0       .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT  DAY  HOUR   ACTIVC4   AREAC4   SEG4  QUANT4  ACTIVC5   AREAC5   SEG5  QUANT5  ACTIVC6   AREAC6   SEG6  QUANT6
 ----  ----  -----  ---  ----   -------   ------   ----  ------  -------   ------   ----  ------  -------   ------   ----  ------
  4     1     1     30    9                          0      .0                       0      .0                       0      .0

                         10                          0      .0                       0      .0                       0      .0

                         11                          0      .0                       0      .0                       0      .0

                         12                          0      .0                       0      .0                       0      .0

                         13                          0      .0                       0      .0                       0      .0

                         14                          0      .0                       0      .0                       0      .0

                    31    7                          0      .0                       0      .0                       0      .0
                          8                          0      .0                       0      .0                       0      .0
                          9                          0      .0                       0      .0                       0      .0
                         10                          0      .0                       0      .0                       0      .0
                         11                          0      .0                       0      .0                       0      .0
                         12                          0      .0                       0      .0                       0      .0
                         13                          0      .0                       0      .0                       0      .0
                         14                          0      .0                       0      .0                       0      .0
              2     21   15                          0      .0                       0      .0                       0      .0

                         16                          0      .0                       0      .0                       0      .0

                         17                          0      .0                       0      .0                       0      .0

                         18                          0      .0                       0      .0                       0      .0

                         19                          0      .0                       0      .0                       0      .0

                         20                          0      .0                       0      .0                       0      .0

                         21                          0      .0                       0      .0                       0      .0

                         22                          0      .0                       0      .0                       0      .0

                    22   15                          0      .0                       0      .0                       0      .0

                         16                          0      .0                       0      .0                       0      .0

                         17                          0      .0                       0      .0                       0      .0

                         18                          0      .0                       0      .0                       0      .0

                         19                          0      .0                       0      .0                       0      .0

                         20                          0      .0                       0      .0                       0      .0

                         21                          0      .0                       0      .0                       0      .0

                         22                          0      .0                       0      .0                       0      .0
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT  SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ----   -    -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4     1      2     22   22                      0       .0                     0      .0                     0      .0
                     23   15                      0       .0                     0      .0                     0      .0

                          16                      0       .0                     0      .0                     0      .0

                          17                      0       .0                     0      .0                     0      .0

                          18                      0       .0                     0      .0                     0      .0

                          19                      0       .0                     0      .0                     0      .0

                          20                      0       .0                     0      .0                     0      .0

                          21                      0       .0                     0      .0                     0      .0

                          22                      0       .0                     0      .0                     0      .0

                     24   15                      0       .0                     0      .0                     0      .0
                          16                      0       .0                     0      .0                     0      .0
                          17                      0       .0                     0      .0                     0      .0
                          18                      0       .0                     0      .0                     0      .0
                          19                      0       .0                     0      .0                     0      .0
                          20                      0       .0                     0      .0                     0      .0
                          21                      0       .0                     0      .0                     0      .0
                          22                      0       .0                     0      .0                     0      .0
               3     22    0                      0       .0                     0      .0                     0      .0
                           1                      0       .0                     0      .0                     0      .0
                           2                      0       .0                     0      .0                     0      .0
                           3                      0       .0                     0      .0                     0      .0
                           4                      0       .0                     0      .0                     0      .0
                           5                      0       .0                     0      .0                     0      .0
                           6                      0       .0                     0      .0                     0      .0
                          23                      0       .0                     0      .0                     0      .0
                     23    0                      0       .0                     0      .0                     0      .0
                           1                      0       .0                     0      .0                     0      .0
                           2                      0       .0                     0      .0                     0      .0
                           3                      0       .0                     0      .0                     0      .0
                           4                      0       .0                     0      .0                     0      .0
                           5                      0       .0                     0      .0                     0      .0
                           6                      0       .0                     0      .0                     0      .0
                          23                      0       .0                     0      .0                     0      .0
                     24    0   LOAD     IOA       0    153.0                     0      .0                     0      .0
                           1   LOAD     IOA       0    153.0                     0      .0                     0      .0
                           2   LOAD     IOA       0    153.0                     0      .0                     0      .0
                           3   LOAD     IOA       0    153.0                     0      .0                     0      .0
                           4   LOAD     IOA       0    153.0                     0      .0                     0      .0
                           5   LOAD     IOA       0    153.0                     0      .0                     0      .0
                           6   LOAD     IOA       0    153.0                     0      .0                     0      .0
                          23   LOAD     IOA       0    153.0                     0      .0                     0      .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT  DAY HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- ----  -----  --- ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4    2     1     1    7   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                        8   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                        9   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       10   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       11   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       12   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       13   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       14   HAUL     HAU     30       4.3  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                   2    7   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                        8   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                        9   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       10   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       11   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       12   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       13   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                       14   HAUL     HAU     30      10.1  VEHI     HAU     0       31.3  PUBL     PUB     0         .9
                   3    7   PUBL     PUB     0         .9                   0         .0                    0         .0
                        8   PUBL     PUB     0         .9                   0         .0                    0         .0
                        9   PUBL     PUB     0         .9                   0         .0                    0         .0
                       10   PUBL     PUB     0         .9                   0         .0                    0         .0
                       11   PUBL     PUB     0         .9                   0         .0                    0         .0
                       12   PUBL     PUB     0         .9                   0         .0                    0         .0
                       13   PUBL     PUB     0         .9                   0         .0                    0         .0
                       14   PUBL     PUB     0         .9                   0         .0                    0         .0
             2     1   15   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       16   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       17   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       18   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       19   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       20   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       21   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                       22   SCRA     SCR     0        22.5  HAUL     HAU     30       9.0  VEHI     HAU     0       18.8
                   2   15   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       16   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       17   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       18   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       19   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       20   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       21   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                       22   SCRA     SCR     0        45.0  PUBL     PUB     0         .9                    0         .0
                  30   15   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       16   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       17   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       18   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       19   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       20   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       21   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
                       22   VEHI     HAU     0        18.8  PUBL     PUB     0         .9  GRAD     GRA     0        1.0
             3     1    0   PUBL     PUB     0          .9                  0         .0                    0         .0
                        1   PUBL     PUB     0          .9                  0         .0                    0         .0
                        2   PUBL     PUB     0          .9                  0         .0                    0         .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- ----  -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4    2     3     1     3  PUBL     PUB        0      .9                      0      .0                      0      .0
                         4  PUBL     PUB        0      .9                      0      .0                      0      .0
                         5  PUBL     PUB        0      .9                      0      .0                      0      .0
                         6  PUBL     PUB        0      .9                      0      .0                      0      .0
                        23  PUBL     PUB        0      .9                      0      .0                      0      .0
                   2     0  PUBL     PUB        0      .9                      0      .0                      0      .0
                         1  PUBL     PUB        0      .9                      0      .0                      0      .0
                         2  PUBL     PUB        0      .9                      0      .0                      0      .0
                         3  PUBL     PUB        0      .9                      0      .0                      0      .0
                         4  PUBL     PUB        0      .9                      0      .0                      0      .0
                         5  PUBL     PUB        0      .9                      0      .0                      0      .0
                         6  PUBL     PUB        0      .9                      0      .0                      0      .0
                        23  PUBL     PUB        0      .9                      0      .0                      0      .0
                   3     0                      0      .0                      0      .0                      0      .0
                         1                      0      .0                      0      .0                      0      .0
                         2                      0      .0                      0      .0                      0      .0
                         3                      0      .0                      0      .0                      0      .0
                         4                      0      .0                      0      .0                      0      .0
                         5                      0      .0                      0      .0                      0      .0
                         6                      0      .0                      0      .0                      0      .0
                        23                      0      .0                      0      .0                      0      .0
```

```
ACTIVITY DATA BASE - PART 2
MINE VISIT SHIFT  DAY  HOUR  ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
---- ----- -----  ---  ----  -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4    3     1     1     7   PUBL     PUB      0       .9                     0      .0                     0      .0
                         8   PUBL     PUB      0       .9                     0      .0                     0      .0
                         9   PUBL     PUB      0       .9                     0      .0                     0      .0
                        10   PUBL     PUB      0       .9                     0      .0                     0      .0
                        11   PUBL     PUB      0       .9                     0      .0                     0      .0
                        12   PUBL     PUB      0       .9                     0      .0                     0      .0
                        13   PUBL     PUB      0       .9                     0      .0                     0      .0
                        14   PUBL     PUB      0       .9                     0      .0                     0      .0
                   2     2                     0       .0                     0      .0                     0      .0
                         7   PUBL     PUB      0       .9                     0      .0                     0      .0
                         8   PUBL     PUB      0       .9                     0      .0                     0      .0
                         9   PUBL     PUB      0       .9                     0      .0                     0      .0
                        10   PUBL     PUB      0       .9                     0      .0                     0      .0
                        11   PUBL     PUB      0       .9                     0      .0                     0      .0
                        12   PUBL     PUB      0       .9                     0      .0                     0      .0
                        13   PUBL     PUB      0       .9                     0      .0                     0      .0
                        14   PUBL     PUB      0       .9                     0      .0                     0      .0
                  31     1                     0       .0                     0      .0                     0      .0
                         7   PUBL     PUB      0       .9                     0      .0                     0      .0
                         8   PUBL     PUB      0       .9                     0      .0                     0      .0
                         9   PUBL     PUB      0       .9                     0      .0                     0      .0
                        10   PUBL     PUB      0       .9                     0      .0                     0      .0
                        11   PUBL     PUB      0       .9                     0      .0                     0      .0
                        12   PUBL     PUB      0       .9                     0      .0                     0      .0
                        13   PUBL     PUB      0       .9                     0      .0                     0      .0
                        14   PUBL     PUB      0       .9                     0      .0                     0      .0
             2     1    15   PUBL     PUB      0       .9                     0      .0                     0      .0
                        16   PUBL     PUB      0       .9                     0      .0                     0      .0
                        17   PUBL     PUB      0       .9                     0      .0                     0      .0
                        18   PUBL     PUB      0       .9                     0      .0                     0      .0
                        19   PUBL     PUB      0       .9                     0      .0                     0      .0
                        20   PUBL     PUB      0       .9                     0      .0                     0      .0
                        21   PUBL     PUB      0       .9                     0      .0                     0      .0
                        22   PUBL     PUB      0       .9                     0      .0                     0      .0
                   2    15   PUBL     PUB      0       .9                     0      .0                     0      .0
                        16   PUBL     PUB      0       .9                     0      .0                     0      .0
                        17   PUBL     PUB      0       .9                     0      .0                     0      .0
                        18   PUBL     PUB      0       .9                     0      .0                     0      .0
                        19   PUBL     PUB      0       .9                     0      .0                     0      .0
                        20   PUBL     PUB      0       .9                     0      .0                     0      .0
                        21   PUBL     PUB      0       .9                     0      .0                     0      .0
                        22   PUBL     PUB      0       .9                     0      .0                     0      .0
                  31    15   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        16   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        17   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        18   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        19   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        20   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        21   VEHI     HAU      0     31.3                     0      .0                     0      .0
                        22   VEHI     HAU      0     31.3                     0      .0                     0      .0
             3     1     0   PUBL     PUB      0       .9
```

```
ACTIVITY DATA BASE - PART 2
 MINE VISIT SHIFT  DAY  HOUR   ACTIVC4  AREAC4  SEG4  QUANT4  ACTIVC5  AREAC5  SEG5  QUANT5  ACTIVC6  AREAC6  SEG6  QUANT6
 ---- ----- -----  ---  ----   -------  ------  ----  ------  -------  ------  ----  ------  -------  ------  ----  ------
  4     3     3      1     1   PUBL     PUB      0       .9                      0       .0                      0      .0
                           2   PUBL     PUB      0       .9                      0       .0                      0      .0
                           3   PUBL     PUB      0       .9                      0       .0                      0      .0
                           4   PUBL     PUB      0       .9                      0       .0                      0      .0
                           5   PUBL     PUB      0       .9                      0       .0                      0      .0
                           6   PUBL     PUB      0       .9                      0       .0                      0      .0
                          23   PUBL     PUB      0       .9                      0       .0                      0      .0
                    30     0   PUBL     PUB      0       .9                      0       .0                      0      .0
                           1   PUBL     PUB      0       .9                      0       .0                      0      .0
                           2   PUBL     PUB      0       .9                      0       .0                      0      .0
                           3   PUBL     PUB      0       .9                      0       .0                      0      .0
                           4   PUBL     PUB      0       .9                      0       .0                      0      .0
                           5   PUBL     PUB      0       .9                      0       .0                      0      .0
                           6   PUBL     PUB      0       .9                      0       .0                      0      .0
                          23   PUBL     PUB      0       .9                      0       .0                      0      .0
                    31     0   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                           1   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                           2   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                           3   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                           4   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                           5   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                           6   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
                          23   VEHI     HAU      0     18.8  PUBL     PUB      0       .9                      0      .0
```

```
ACTIVITY DATA BASE - PART 3
MINE VISIT SHIFT DAY  HOUR   SEG7  QUANT7    SEG8  QUANT8    SEG9  QUANT9
---- ----  ----- ---  ----   ----  ------    ----  ------    ----  ------
 1    1     1    24    16     0       .0      0       .0      0       .0
                       17     0       .0      0       .0      0       .0
                       18     0       .0      0       .0      0       .0
                       19     0       .0      0       .0      0       .0
                       20     0       .0      0       .0      0       .0
                       21     0       .0      0       .0      0       .0
                       22     0       .0      0       .0      0       .0
                       23     0       .0      0       .0      0       .0
                 25     0     0       .0      0       .0      0       .0
                        1     0       .0      0       .0      0       .0
                        2     0       .0      0       .0      0       .0
                        3     0       .0      0       .0      0       .0
                        4     0       .0      0       .0      0       .0
                        5     0       .0      0       .0      0       .0
                        6     0       .0      0       .0      0       .0
                        7     2      5.0      0       .0      0       .0
                        8     0       .0      0       .0      0       .0
                        9     1      4.0      0       .0      0       .0
                       10     0       .0      0       .0      0       .0
                       11     0       .0      0       .0      0       .0
                       12     1      4.0      0       .0      0       .0
                       13     0       .0      0       .0      0       .0
                       14     0       .0      0       .0      0       .0
                       15     0       .0      0       .0      0       .0
                       16     0       .0      0       .0      0       .0
                       17     0       .0      0       .0      0       .0
                       18     0       .0      0       .0      0       .0
                       19     0       .0      0       .0      0       .0
                       20     0       .0      0       .0      0       .0
                       21     0       .0      0       .0      0       .0
                       22     0       .0      0       .0      0       .0
                       23     0       .0      0       .0      0       .0
                 26     0     0       .0      0       .0      0       .0
                        1     0       .0      0       .0      0       .0
                        2     0       .0      0       .0      0       .0
                        3     0       .0      0       .0      0       .0
                        4     0       .0      0       .0      0       .0
                        5     0       .0      0       .0      0       .0
                        6     0       .0      0       .0      0       .0
                        7     2      5.0      0       .0      0       .0
                        8     1      4.0      2      3.0      0       .0
                        9     2      3.0      0       .0      0       .0
                       10     2      3.0      0       .0      0       .0
                       11     2      5.0      0       .0      0       .0
                       12     2      3.0      0       .0      0       .0
                       13     2      3.0      0       .0      0       .0
                       14     2      3.0      0       .0      0       .0
                       15     0       .0      0       .0      0       .0
                       16     0       .0      0       .0      0       .0
                       17     0       .0      0       .0      0       .0
                       18     0       .0      0       .0      0       .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT  SHIFT  DAY  HOUR    SEG7  QUANT7    SEG8  QUANT8    SEG9  QUANT9
 ----  ----  -----  ---  ----    ----  ------    ----  ------    ----  ------
 1     1     1      26   19      0         .0    0         .0    0         .0
                         20      0         .0    0         .0    0         .0
                         21      0         .0    0         .0    0         .0
                         22      0         .0    0         .0    0         .0
                         23      0         .0    0         .0    0         .0
                    27    0      0         .0    0         .0    0         .0
                          1      0         .0    0         .0    0         .0
                          2      0         .0    0         .0    0         .0
                          3      0         .0    0         .0    0         .0
                          4      0         .0    0         .0    0         .0
                          5      0         .0    0         .0    0         .0
                          6      0         .0    0         .0    0         .0
                          7      2        5.0    0         .0    0         .0
                          8      1        4.0    0         .0    0         .0
                          9      0       20.0    1        4.0    0         .0
                         10      1        4.0    0         .0    0         .0
                         11      1        6.0    0         .0    0         .0
                         12      1        4.0    0         .0    0         .0
                         13      1        4.0    0         .0    0         .0
                         14      1        4.0    0         .0    0         .0
                         15      0         .0    0         .0    0         .0
                         16      0         .0    0         .0    0         .0
                         17      0         .0    0         .0    0         .0
                         18      0         .0    0         .0    0         .0
                         19      0         .0    0         .0    0         .0
                         20      0         .0    0         .0    0         .0
                         21      0         .0    0         .0    0         .0
                         22      0         .0    0         .0    0         .0
                         23      0         .0    0         .0    0         .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT   DAY  HOUR     SEG7   QUANT7     SEG8   QUANT8     SEG9   QUANT9
 ----  -----  -----   ---  ----     ----   ------     ----   ------     ----   ------
  1      2      1     21     7        0       .0        0       .0        0       .0
                             8        0       .0        0       .0        0       .0
                             9        0       .0        0       .0        0       .0
                            10        0       .0        0       .0        0       .0
                            11        0       .0        0       .0        0       .0
                            12        0       .0        0       .0        0       .0
                            13        0       .0        0       .0        0       .0
                            14        0       .0        0       .0        0       .0
                      22     7        0       .0        0       .0        0       .0
                             8        0       .0        0       .0        0       .0
                             9        0       .0        0       .0        0       .0
                            10        0       .0        0       .0        0       .0
                            11        0       .0        0       .0        0       .0
                            12        0       .0        0       .0        0       .0
                            13        0       .0        0       .0        0       .0
                            14        0       .0        0       .0        0       .0
                      23     7        0       .0        0       .0        0       .0
                             8        0       .0        0       .0        0       .0
                             9        0       .0        0       .0        0       .0
                            10        0       .0        0       .0        0       .0
                            11        0       .0        0       .0        0       .0
                            12        0       .0        0       .0        0       .0

                            13        0       .0        0       .0        0       .0
                            14        0       .0        0       .0        0       .0
                2     21    15        0       .0        0       .0        0       .0
                            16        0       .0        0       .0        0       .0
                            17        0       .0        0       .0        0       .0
                            18        0       .0        0       .0        0       .0
                            19        0       .0        0       .0        0       .0
                            20        0       .0        0       .0        0       .0
                            21        0       .0        0       .0        0       .0
                            22        0       .0        0       .0        0       .0
                      22    15        0       .0        0       .0        0       .0
                            16        0       .0        0       .0        0       .0
                            17        0       .0        0       .0        0       .0
                            18        0       .0        0       .0        0       .0
                            19        0       .0        0       .0        0       .0
                            20        0       .0        0       .0        0       .0
                            21        0       .0        0       .0        0       .0
                            22        0       .0        0       .0        0       .0
                3     22     0        0       .0        0       .0        0       .0
                             1        0       .0        0       .0        0       .0
                             2        0       .0        0       .0        0       .0
                             3        0       .0        0       .0        0       .0
                             4        0       .0        0       .0        0       .0
                             5        0       .0        0       .0        0       .0
                             6        0       .0        0       .0        0       .0
                            23        0       .0        0       .0        0       .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT  SHIFT  DAY  HOUR     SEG7  QUANT7     SEG8  QUANT8     SEG9  QUANT9
 ----  ----  -----  ---  ----     ----  ------     ----  ------     ----  ------
 1      3     1     19    7        0        .0      0        .0      0        .0
                          8        0        .0      0        .0      0        .0
                          9        0        .0      0        .0      0        .0
                         10        0        .0      0        .0      0        .0
                                   0        .0      0        .0      0        .0
                         11        0        .0      0        .0      0        .0
                         12        0        .0      0        .0      0        .0
                         13        0        .0      0        .0      0        .0
                         14        0        .0      0        .0      0        .0
                        20        1        0        .0      0        .0      0        .0
                          7        0        .0      0        .0      0        .0
                          8        0        .0      0        .0      0        .0
                          9        0        .0      0        .0      0        .0
                         10        0        .0      0        .0      0        .0
                         11        0        .0      0        .0      0        .0
                         12        0        .0      0        .0      0        .0
                         13        0        .0      0        .0      0        .0
                         14        0        .0      0        .0      0        .0
                    21    7        0        .0      0        .0      0        .0
                          8        0        .0      0        .0      0        .0
                          9        0        .0      0        .0      0        .0
                         10        0        .0      0        .0      0        .0
                         11        0        .0      0        .0      0        .0

                         12        0        .0      0        .0      0        .0
                         13        0        .0      0        .0      0        .0
                         14        0        .0      0        .0      0        .0
              2     19   15        0        .0      0        .0      0        .0
                         16        0        .0      0        .0      0        .0
                         17        0        .0      0        .0      0        .0
                         18        0        .0      0        .0      0        .0
                         19        0        .0      0        .0      0        .0
                         20        0        .0      0        .0      0        .0
                         21        0        .0      0        .0      0        .0
                         22        0        .0      0        .0      0        .0
              3     19    0        0        .0      0        .0      0        .0
                          1        0        .0      0        .0      0        .0
                          2        0        .0      0        .0      0        .0
                          3        0        .0      0        .0      0        .0
                          4        0        .0      0        .0      0        .0
                          5        0        .0      0        .0      0        .0
                          6        0        .0      0        .0      0        .0
                         23        0        .0      0        .0      0        .0
                    20    0        0        .0      0        .0      0        .0
                          1        0        .0      0        .0      0        .0
                          2        0        .0      0        .0      0        .0
                          3        0        .0      0        .0      0        .0
                          4        0        .0      0        .0      0        .0
                          5        0        .0      0        .0      0        .0
                          6        0        .0      0        .0      0        .0
                         23        0        .0      0        .0      0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT SHIFT  DAY  HOUR    SEG7  QUANT7     SEG8  QUANT8      SEG9  QUANT9
 ----  ----  -----  ---  ----    ----  ------     ----  ------      ----  ------
 2      1     1      8   23      0        .0      0        .0       0        .0
                     9    0      0        .0      0        .0       0        .0
                          1      0        .0      0        .0       0        .0
                          2      0        .0      0        .0       0        .0
                          3      0        .0      0        .0       0        .0
                          4      0        .0      0        .0       0        .0
                          5      0        .0      0        .0       0        .0
                          6      0        .0      0        .0       0        .0
                          7      0    1200.0      0       1.0       0      61.0
                          8      0    1200.0      0       1.0       0      61.0
                          9      0    1200.0      0       1.0       0      61.0
                         10      0    1200.0      0      61.0       0        .0
                         11      0    1200.0      0      61.0       0        .0
                         12      0    1200.0      0      61.0       0        .0
                         13      0    1200.0      0      61.0       0        .0
                         14      0    1200.0      0      61.0       0        .0
                         15      0        .0      0        .0       0        .0
                         16      0        .0      0        .0       0        .0
                         17      0        .0      0        .0       0        .0
                         18      0        .0      0        .0       0        .0
                         19      0        .0      0        .0       0        .0
                         20      0        .0      0        .0       0        .0
                         21      0        .0      0        .0       0        .0
                         22      0        .0      0        .0       0        .0
                         23      0        .0      0        .0       0        .0
                    10    0      0        .0      0        .0       0        .0
                          1      0        .0      0        .0       0        .0
                          2      0        .0      0        .0       0        .0
                          3      0        .0      0        .0       0        .0
                          4      0        .0      0        .0       0        .0
                          5      0        .0      0        .0       0        .0
                          6      0        .0      0        .0       0        .0
                          7      1     703.8      2     375.7       0      61.0
                          8      1     703.8      2     375.5       0      61.0
                          9      1     703.8      2     375.7       0      61.0
                         10      1     703.8      2     375.7       0      61.0
                         11      1     703.8      2     375.7       0      61.0
                         12      1     703.8      2     375.7       0      61.0
                         13      1     703.8      2     375.7       0      61.0
                         14      1     703.8      2     375.7       0      61.0
                         15      1     703.8      2     375.7       0      49.0
                         16      1     703.8      2     375.7       0      49.0
                         17      1     703.8      2     375.7       0      49.0
                         18      1     703.8      2     375.7       0      49.0
                         19      1     703.8      2     375.7       0      49.0
                         20      1     703.8      2     375.7       0      49.0
                         21      1     703.8      2     375.7       0      49.0
                         22      1     703.8      2     375.7       0      49.0
                         23      0        .0      0        .0       0        .0
                    11    0      0        .0      0        .0       0        .0
                          1      0        .0      0        .0       0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT  SHIFT  DAY  HOUR     SEG7  QUANT7     SEG8  QUANT8      SEG9  QUANT9
 ----  ----  -----  ---  ----     ----  ------     ----  ------      ----  ------
 2     1     1      11     2       0        .0      0        .0       0        .0
                           3       0        .0      0        .0       0        .0
                           4       0        .0      0        .0       0        .0
                           5       0        .0      0        .0       0        .0
                           6       0        .0      0        .0       0        .0
                           7       0        .0      0        .0       0        .0
                           8       0        .0      0        .0       0        .0
                           9       0        .0      0        .0       0        .0
                          10       0        .0      0        .0       0        .0
                          11       0        .0      0        .0       0        .0
                          12       0        .0      0        .0       0        .0
                          13       0        .0      0        .0       0        .0
                          14       0        .0      0        .0       0        .0
                          15       0        .0      0        .0       0        .0
                          16       0        .0      0        .0       0        .0
                          17       0        .0      0        .0       0        .0
                          18       0        .0      0        .0       0        .0
                          19       0        .0      0        .0       0        .0
                          20       0        .0      0        .0       0        .0
                          21       0        .0      0        .0       0        .0
                          22       0        .0      0        .0       0        .0
                          23       0        .0      0        .0       0        .0
                    12     0       0        .0      0        .0       0        .0
                           1       0        .0      0        .0       0        .0
                           2       0        .0      0        .0       0        .0
                           3       0        .0      0        .0       0        .0
                           4       0        .0      0        .0       0        .0
                           5       0        .0      0        .0       0        .0
                           6       0        .0      0        .0       0        .0
                           7       0        .0      0        .0       0        .0
                           8       0        .0      0        .0       0        .0
                           9       0        .0      0        .0       0        .0
                          10       0        .0      0        .0       0        .0
                          11       0        .0      0        .0       0        .0
                                   0        .0      0        .0       0        .0
                          12       0        .0      0        .0       0        .0
                          13       0        .0      0        .0       0        .0
                          14       0        .0      0        .0       0        .0
                          15       0        .0      0        .0       0        .0
                          16       0        .0      0        .0       0        .0
                          17       0        .0      0        .0       0        .0
                          18       0        .0      0        .0       0        .0
                          19       0        .0      0        .0       0        .0
                          20       0        .0      0        .0       0        .0
                          21       0        .0      0        .0       0        .0
                          22       0        .0      0        .0       0        .0
                          23       0        .0      0        .0       0        .0
                    13     0       0        .0      0        .0       0        .0
                           1       0        .0      0        .0       0        .0
                           2       0        .0      0        .0       0        .0
                           3       0        .0      0        .0       0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT  DAY  HOUR    SEG7  QUANT7    SEG8  QUANT8    SEG9  QUANT9
 ----  ----   -----  ---  ----    ----  ------    ----  ------    ----  ------
 2     1      1      13    4       0       .0      0       .0      0       .0
                           5       0       .0      0       .0      0       .0
                           6       0       .0      0       .0      0       .0
                           7       0      1.0      0     61.0      0       .0
                           8       0      1.0      0     61.0      0       .0
                           9       0      1.0      0     61.0      0       .0
                          10       0     61.0      0       .0      0       .0
                          11       0     61.0      0       .0      0       .0
                          12       0     61.0      0       .0      0       .0
                          13       0     61.0      0       .0      0       .0
                          14       0     61.0      0       .0      0       .0
                          15       0     49.0      0       .0      0       .0
                          16       0     49.0      0       .0      0       .0
                          17       0     49.0      0       .0      0       .0
                          18       0     49.0      0       .0      0       .0
                          19       0     49.0      0       .0      0       .0
                          20       0     49.0      0       .0      0       .0
                          21       0     49.0      0       .0      0       .0
                          22       0     49.0      0       .0      0       .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT  SHIFT  DAY  HOUR      SEG7  QUANT7     SEG8  QUANT8     SEG9  QUANT9
 ---- -----  -----  ---  ----      ----  ------     ----  ------     ----  ------
  2     3      1     11    7        0        .0      0        .0      0        .0
                           8        0        .0      0        .0      0        .0
                           9        0        .0      0        .0      0        .0
                          10        0        .0      0        .0      0        .0
                          11        0        .0      0        .0      0        .0
                          12        0        .0      0        .0      0        .0
                          13        0        .0      0        .0      0        .0
                          14        0        .0      0        .0      0        .0
                     12    7        0        .0      0        .0      0        .0
                           8        0        .0      0        .0      0        .0
                           9        0        .0      0        .0      0        .0
                          10        0        .0      0        .0      0        .0
                          11        0        .0      0        .0      0        .0
                          12        0        .0      0        .0      0        .0
                          13        0        .0      0        .0      0        .0
                          14        0        .0      0        .0      0        .0
                     13    7        0        .0      0        .0      0        .0
                           8        0        .0      0        .0      0        .0
                           9        0        .0      0        .0      0        .0
                          10        0        .0      0        .0      0        .0
                          11        0        .0      0        .0      0        .0
                          12        0        .0      0        .0      0        .0
                          13        0        .0      0        .0      0        .0
                          14        0        .0      0        .0      0        .0
               2     11   15        0        .0      0        .0      0        .0
                          16        0        .0      0        .0      0        .0
                          17        0        .0      0        .0      0        .0
                          18        0        .0      0        .0      0        .0
                          19        0        .0      0        .0      0        .0
                          20        0        .0      0        .0      0        .0
                          21        0        .0      0        .0      0        .0
                          22        0        .0      0        .0      0        .0
                     12   15        0        .0      0        .0      0        .0
                          16        0        .0      0        .0      0        .0
                          17        0        .0      0        .0      0        .0
                          18        0        .0      0        .0      0        .0
                          19        0        .0      0        .0      0        .0
                          20        0        .0      0        .0      0        .0
                          21        0        .0      0        .0      0        .0
                          22        0        .0      0        .0      0        .0
                     13   15        0        .0      0        .0      0        .0
                          16        0        .0      0        .0      0        .0
                          17        0        .0      0        .0      0        .0
                          18        0        .0      0        .0      0        .0
                          19        0        .0      0        .0      0        .0
                          20        0        .0      0        .0      0        .0
                          21        0        .0      0        .0      0        .0
                          22        0        .0      0        .0      0        .0
               3     11    0        0        .0      0        .0      0        .0
                           1        0        .0      0        .0      0        .0
                           2        0        .0      0        .0      0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT SHIFT  DAY  HOUR      SEG7  QUANT7      SEG8  QUANT8      SEG9  QUANT9
 ----  -----  -----  ---  ----      ----  ------      ----  ------      ----  ------
 2      3      3     11    3        0        .0      0        .0      0        .0
                           4        0        .0      0        .0      0        .0
                           5        0        .0      0        .0      0        .0
                           6        0        .0      0        .0      0        .0
                          23        0        .0      0        .0      0        .0
                     12    0        0        .0      0        .0      0        .0
                           1        0        .0      0        .0      0        .0
                           2        0        .0      0        .0      0        .0
                           3        0        .0      0        .0      0        .0
                           4        0        .0      0        .0      0        .0
                           5        0        .0      0        .0      0        .0
                           6        0        .0      0        .0      0        .0
                          23        0        .0      0        .0      0        .0
                     13    0        0        .0      0        .0      0        .0
                           1        0        .0      0        .0      0        .0
                           2        0        .0      0        .0      0        .0
                           3        0        .0      0        .0      0        .0
                           4        0        .0      0        .0      0        .0
                           5        0        .0      0        .0      0        .0
                           6        0        .0      0        .0      0        .0
                          23        0        .0      0        .0      0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT  SHIFT  DAY  HOUR      SEG7  QUANT7     SEG8  QUANT8      SEG9  QUANT9
 ----  ----  -----  ---  ----      ----  ------     ----  ------      ----  ------
 3     3     1      11    7         0        .0      0        .0       0        .0
                          8         0        .0      0        .0       0        .0
                          9         0        .0      0        .0       0        .0
                         10         0        .0      0        .0       0        .0
                         11         0        .0      0        .0       0        .0
                         12         0        .0      0        .0       0        .0
                         13         0        .0      0        .0       0        .0
                         14         0        .0      0        .0       0        .0
                    12    7         0        .0      0        .0       0        .0
                          8         0        .0      0        .0       0        .0
                          9         0        .0      0        .0       0        .0
                         10         0        .0      0        .0       0        .0
                         11         0        .0      0        .0       0        .0
                         12         0        .0      0        .0       0        .0
                         13         0        .0      0        .0       0        .0
                         14         0        .0      0        .0       0        .0
                    17    8         0        .0      0        .0       0        .0
                    18    5         0        .0      0        .0       0        .0
                          7         0        .0      0        .0       0        .0
                          8         0        .0      0        .0       0        .0
                          9         0        .0      0        .0       0        .0
                         10         0        .0      0        .0       0        .0
                         11         0        .0      0        .0       0        .0
                         12         0        .0      0        .0       0        .0
                         13         0        .0      0        .0       0        .0
                         14         0        .0      0        .0       0        .0
                    19    7         0        .0      0        .0       0        .0
                          8         0        .0      0        .0       0        .0
                          9         0        .0      0        .0       0        .0
                         10         0        .0      0        .0       0        .0
                         11         0        .0      0        .0       0        .0
                         12         0        .0      0        .0       0        .0
                         13         0        .0      0        .0       0        .0
                         14         0        .0      0        .0       0        .0
                    20    7         0        .0      0        .0       0        .0
                          8         0        .0      0        .0       0        .0
                          9         0        .0      0        .0       0        .0
                         10         0        .0      0        .0       0        .0
                         11         0        .0      0        .0       0        .0
                         12         0        .0      0        .0       0        .0
                         13         0        .0      0        .0       0        .0
                         14         0        .0      0        .0       0        .0
             2      11   15         0        .0      0        .0       0        .0
                         16         0        .0      0        .0       0        .0
                         17         0        .0      0        .0       0        .0
                         18         0        .0      0        .0       0        .0
                         19         0        .0      0        .0       0        .0
                         20         0        .0      0        .0       0        .0
                         21         0        .0      0        .0       0        .0
                         22         0        .0      0        .0       0        .0
                    12   15         0        .0      0        .0       0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT  DAY  HOUR     SEG7   QUANT7     SEG8   QUANT8      SEG9   QUANT9
 ----  ----   -----  ---  ----     ----   ------     ----   ------      ----   ------
  3     3      2     12    16       0         .0      0         .0       0         .0
                           17       0         .0      0         .0       0         .0
                           18       0         .0      0         .0       0         .0
                           19       0         .0      0         .0       0         .0
                           20       0         .0      0         .0       0         .0
                           21       0         .0      0         .0       0         .0
                           22       0         .0      0         .0       0         .0
                     13    15       0         .0      0         .0       0         .0
                           16       0         .0      0         .0       0         .0
                           17       0         .0      0         .0       0         .0
                           18       0         .0      0         .0       0         .0
                           19       0         .0      0         .0       0         .0
                           20       0         .0      0         .0       0         .0
                           21       0         .0      0         .0       0         .0
                           22       0         .0      0         .0       0         .0
                     17    15       0         .0      0         .0       0         .0
                           16       0         .0      0         .0       0         .0
                           17       0         .0      0         .0       0         .0
                           18       0         .0      0         .0       0         .0
                           19       0         .0      0         .0       0         .0
                           20       0         .0      0         .0       0         .0
                           21       0         .0      0         .0       0         .0
                           22       0         .0      0         .0       0         .0
                     18    15       0         .0      0         .0       0         .0
                           16       0         .0      0         .0       0         .0
                           17       0         .0      0         .0       0         .0
                           18       0         .0      0         .0       0         .0
                           19       0         .0      0         .0       0         .0
                           20       0         .0      0         .0       0         .0
                           21       0         .0      0         .0       0         .0
                           22       0         .0      0         .0       0         .0
                     19    15       0         .0      0         .0       0         .0
                           16       0         .0      0         .0       0         .0
                           17       0         .0      0         .0       0         .0
                           18       0         .0      0         .0       0         .0
                           19       0         .0      0         .0       0         .0
                           20       0         .0      0         .0       0         .0
                           21       0         .0      0         .0       0         .0
                           22       0         .0      0         .0       0         .0
               3     11     0       0         .0      0         .0       0         .0
                            1       0         .0      0         .0       0         .0
                            2       0         .0      0         .0       0         .0
                            3       0         .0      0         .0       0         .0
                            4       0         .0      0         .0       0         .0
                            5       0         .0      0         .0       0         .0
                            6       0         .0      0         .0       0         .0
                           23       0         .0      0         .0       0         .0
                     12     0       0         .0      0         .0       0         .0
                            1       0         .0      0         .0       0         .0
                            2       0         .0      0         .0       0         .0
                            3       0         .0      0         .0       0         .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT  DAY  HOUR     SEG7  QUANT7      SEG8  QUANT8      SEG9  QUANT9
 ----  ----   ----   ---  ----     ----  ------      ----  ------      ----  ------
 3      3      3     12    4        0        .0       0        .0       0        .0
                           5        0        .0       0        .0       0        .0
                           6        0        .0       0        .0       0        .0
                          23        0        .0       0        .0       0        .0
                     13    0        0        .0       0        .0       0        .0
                           1        0        .0       0        .0       0        .0
                           2        0        .0       0        .0       0        .0
                           3        0        .0       0        .0       0        .0
                           4        0        .0       0        .0       0        .0
                           5        0        .0       0        .0       0        .0
                           6        0        .0       0        .0       0        .0
                          23        0        .0       0        .0       0        .0
                     18    0        0        .0       0        .0       0        .0
                           1        0        .0       0        .0       0        .0
                           2        0        .0       0        .0       0        .0
                           3        0        .0       0        .0       0        .0
                           4        0        .0       0        .0       0        .0
                           5        0        .0       0        .0       0        .0
                           6        0        .0       0        .0       0        .0
                          23        0        .0       0        .0       0        .0
                     19    0        0        .0       0        .0       0        .0
                           1        0        .0       0        .0       0        .0
                           2        0        .0       0        .0       0        .0
                           3        0        .0       0        .0       0        .0
                           4        0        .0       0        .0       0        .0
                           5        0        .0       0        .0       0        .0
                           6        0        .0       0        .0       0        .0
                          23        0        .0       0        .0       0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT  DAY  HOUR      SEG7  QUANT7      SEG8  QUANT8      SEG9  QUANT9
 ----  ----   -----  ---  ----      ----  ------      ----  ------      ----  ------
 3      1      1      1     7        0        .0       0        .0       0        .0

                            8        0        .0       0        .0       0        .0

                            9        0        .0       0        .0       0        .0

                           10        0        .0       0        .0       0        .0

                           11        0        .0       0        .0       0        .0

                           12        0        .0       0        .0       0        .0

                           13        0        .0       0        .0       0        .0

                           14        0        .0       0        .0       0        .0

                      2     7        0        .0       0        .0       0        .0

                            8        0        .0       0        .0       0        .0

                            9        0        .0       0         0       0        .0

                           10        0        .0       0        .0       0        .0

                           11        0        .0       0        .0       0        .0

                           12        0        .0       0        .0       0        .0

                           13        0        .0       0        .0       0        .0

                           14        0        .0       0        .0       0        .0

                     21     7        0        .0       0        .0       0        .0

                            8        0        .0       0        .0       0        .0

                            9        0        .0       0        .0       0        .0

                           10        0        .0       0        .0       0        .0

                           11        0        .0       0        .0       0        .0

                           12        0        .0       0        .0       0        .0

                           13        0        .0       0        .0       0        .0
                                                                        0        .0
                           14        0        .0       0        .0       0        .0

                           22        0        .0       0        .0       0        .0
                     22     7        0        .0       0        .0       0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT  SHIFT  DAY  HOUR     SEG7  QUANT7      SEG8  QUANT8      SEG9  QUANT9
 ----  ----  -----  ---  ----     ----  ------      ----  ------      ----  ------
 4     1     1      22    8       0         .0      0         .0      0         .0

                          9       0         .0      0         .0      0         .0

                         10       0         .0      0         .0      0         .0

                         11       0         .0      0         .0      0         .0

                         12       0         .0      0         .0      0         .0

                         13       0         .0      0         .0      0         .0

                         14       0         .0      0         .0      0         .0

                    23    7       0         .0      0         .0      0         .0

                          8       0         .0      0         .0      0         .0

                          9       0         .0      0         .0      0         .0

                         10       0         .0      0         .0      0         .0

                         11       0         .0      0         .0      0         .0

                         12       0         .0      0         .0      0         .0

                         13       0         .0      0         .0      0         .0


                         14       0         .0      0         .0      0         .0

                    24    7       0         .0      0         .0      0         .0

                          8       0         .0      0         .0      0         .0

                          9       0         .0      0         .0      0         .0

                         10       0         .0      0         .0      0         .0

                         11       0         .0      0         .0      0         .0

                         12       0         .0      0         .0      0         .0

                         13       0         .0      0         .0      0         .0

                         14       0         .0      0         .0      0         .0

                    30    7       0         .0      0         .0      0         .0

                          8       0         .0      0         .0      0         .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT   DAY  HOUR     SEG7  QUANT7    SEG8  QUANT8     SEG9  QUANT9
 ----  -----  -----   ---  ----     ----  ------    ----  ------     ----  ------
  4      1      1     30     9       0        .0     0        .0      0        .0

                            10       0        .0     0        .0      0        .0

                            11       0        .0     0        .0      0        .0

                            12       0        .0     0        .0      0        .0

                            13       0        .0     0        .0      0        .0

                            14       0        .0     0        .0      0        .0

                      31     7       0        .0     0        .0      0        .0
                             8       0        .0     0        .0      0        .0
                             9       0        .0     0        .0      0        .0
                            10       0        .0     0        .0      0        .0
                            11       0        .0     0        .0      0        .0
                            12       0        .0     0        .0      0        .0
                            13       0        .0     0        .0      0        .0
                            14       0        .0     0        .0      0        .0
                2     21    15       0        .0     0        .0      0        .0

                            16       0        .0     0        .0      0        .0

                            17       0        .0     0        .0      0        .0

                            18       0        .0     0        .0      0        .0

                            19       0        .0     0        .0      0        .0

                            20       0        .0     0        .0      0        .0

                            21       0        .0     0        .0      0        .0

                            22       0        .0     0        .0      0        .0

                      22    15       0        .0     0        .0      0        .0

                            16       0        .0     0        .0      0        .0

                            17       0        .0     0        .0      0        .0

                            18       0        .0     0        .0      0        .0

                            19       0        .0     0        .0      0        .0

                            20       0        .0     0        .0      0        .0

                            21       0        .0     0        .0      0        .0

                            22       0        .0     0        .0      0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT  DAY  HOUR    SEG7   QUANT7     SEG8   QUANT8     SEG9   QUANT9
 ----  ----   -----  ---  ----    ----   ------     ----   ------     ----   ------
  4      2      1      1     7       0     37.5       20      3.5        0       .0
                             8       0     37.5       20      3.5        0       .0
                             9       0     37.5       20      3.5        0       .0
                            10       0     37.5       20      3.5        0       .0
                            11       0     37.5       20      3.5        0       .0
                            12       0     37.5       20      3.5        0       .0
                            13       0     37.5       20      3.5        0       .0
                            14       0     37.5       20      3.5        0       .0
                       2     7       9       .0        0       .0        0       .0
                             8       9       .0        0       .0        0       .0
                             9       9       .0        0       .0        0       .0
                            10       9       .0        0       .0        0       .0
                            11       9       .0        0       .0        0       .0
                            12       9       .0        0       .0        0       .0
                            13       9       .0        0       .0        0       .0
                            14       9       .0        0       .0        0       .0
                       3     7       0       .0        0       .0        0       .0
                             8       0       .0        0       .0        0       .0
                             9       0       .0        0       .0        0       .0
                            10       0       .0        0       .0        0       .0
                            11       0       .0        0       .0        0       .0
                            12       0       .0        0       .0        0       .0
                            13       0       .0        0       .0        0       .0
                            14       0       .0        0       .0        0       .0
                2      1    15       0       .9        0       .0        0       .0
                            16       0       .9        0       .0        0       .0
                            17       0       .9        0       .0        0       .0
                            18       0       .9        0       .0        0       .0
                            19       0       .9        0       .0        0       .0
                            20       0       .9        0       .0        0       .0
                            21       0       .9        0       .0        0       .0
                            22       0       .9        0       .0        0       .0
                       2    15       0       .0        0       .0        0       .0
                            16       0       .0        0       .0        0       .0
                            17       0       .0        0       .0        0       .0
                            18       0       .0        0       .0        0       .0
                            19       0       .0        0       .0        0       .0
                            20       0       .0        0       .0        0       .0
                            21       0       .0        0       .0        0       .0
                            22       0       .0        0       .0        0       .0
                      30    15      20      5.1        0       .0        0       .0
                            16      20      5.1        0       .0        0       .0
                            17      20      5.1        0       .0        0       .0
                            18      20      5.1        0       .0        0       .0
                            19      20      5.1        0       .0        0       .0
                            20      20      5.1        0       .0        0       .0
                            21      20      5.1        0       .0        0       .0
                            22      20      5.1        0       .0        0       .0
                3      1     0       0       .0        0       .0        0       .0
                             1       0       .0        0       .0        0       .0
                             2       0       .0        0       .0        0       .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT SHIFT DAY  HOUR      SEG7  QUANT7     SEG8  QUANT8      SEG9  QUANT9
 ---- ----  ----- ---  ----      ----  ------     ----  ------      ----  ------
 4      2    3      1     3      0         .0     0         .0     0          .0
                          4      0         .0     0         .0     0          .0
                          5      0         .0     0         .0     0          .0
                          6      0         .0     0         .0     0          .0
                         23      0         .0     0         .0     0          .0
                    2     0      0         .0     0         .0     0          .0
                          1      0         .0     0         .0     0          .0
                          2      0         .0     0         .0     0          .0
                          3      0         .0     0         .0     0          .0
                          4      0         .0     0         .0     0          .0
                          5      0         .0     0         .0     0          .0
                          6      0         .0     0         .0     0          .0
                         23      0         .0     0         .0     0          .0
                    3     0      0         .0     0         .0     0          .0
                          1      0         .0     0         .0     0          .0
                          2      0         .0     0         .0     0          .0
                          3      0         .0     0         .0     0          .0
                          4      0         .0     0         .0     0          .0
                          5      0         .0     0         .0     0          .0
                          6      0         .0     0         .0     0          .0
                         23      0         .0     0         .0     0          .0
```

```
ACTIVITY DATA BASE    PART 3
 MINE VISIT  SHIFT  DAY  HOUR      SEG7   QUANT7     SEG8   QUANT8      SEG9   QUANT9
 ----  ----  -----  ---  ----      ----   ------     ----   ------      ----   ------
 4      1     2     22   22         0       .0        0       .0         0       .0
                    23   15         0       .0        0       .0         0       .0

                         16         0       .0        0       .0         0       .0

                         17         0       .0        0       .0         0       .0

                         18         0       .0        0       .0         0       .0

                         19         0       .0        0       .0         0       .0

                         20         0       .0        0       .0         0       .0

                         21         0       .0        0       .0         0       .0

                         22         0       .0        0       .0         0       .0

                    24   15         0       .0        0       .0         0       .0
                         16         0       .0        0       .0         0       .0
                         17         0       .0        0       .0         0       .0
                         18         0       .0        0       .0         0       .0
                         19         0       .0        0       .0         0       .0
                         20         0       .0        0       .0         0       .0
                         21         0       .0        0       .0         0       .0
                         22         0       .0        0       .0         0       .0
              3     22    0         0       .0        0       .0         0       .0
                          1         0       .0        0       .0         0       .0
                          2         0       .0        0       .0         0       .0
                          3         0       .0        0       .0         0       .0
                          4         0       .0        0       .0         0       .0
                          5         0       .0        0       .0         0       .0
                          6         0       .0        0       .0         0       .0
                         23         0       .0        0       .0         0       .0
                    23    0         0       .0        0       .0         0       .0
                          1         0       .0        0       .0         0       .0
                          2         0       .0        0       .0         0       .0
                          3         0       .0        0       .0         0       .0
                          4         0       .0        0       .0         0       .0
                          5         0       .0        0       .0         0       .0
                          6         0       .0        0       .0         0       .0
                         23         0       .0        0       .0         0       .0
                    24    0         0       .0        0       .0         0       .0
                          1         0       .0        0       .0         0       .0
                          2         0       .0        0       .0         0       .0
                          3         0       .0        0       .0         0       .0
                          4         0       .0        0       .0         0       .0
                          5         0       .0        0       .0         0       .0
                          6         0       .0        0       .0         0       .0
                         23         0       .0        0       .0         0       .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE VISIT SHIFT  DAY  HOUR      SEG7  QUANT7      SEG8  QUANT8      SEG9  QUANT9
 ----  ----  -----  ---  ----      ----  ------      ----  ------      ----  ------
 4      3     1      1    7         0        .0       0        .0       0        .0
                          8         0        .0       0        .0       0        .0
                          9         0        .0       0        .0       0        .0
                         10         0        .0       0        .0       0        .0
                         11         0        .0       0        .0       0        .0
                         12         0        .0       0        .0       0        .0
                         13         0        .0       0        .0       0        .0
                         14         0        .0       0        .0       0        .0
                     2    2         0        .0       0        .0       0        .0
                          7         0        .0       0        .0       0        .0
                          8         0        .0       0        .0       0        .0
                          9         0        .0       0        .0       0        .0
                         10         0        .0       0        .0       0        .0
                         11         0        .0       0        .0       0        .0
                         12         0        .0       0        .0       0        .0
                         13         0        .0       0        .0       0        .0
                         14         0        .0       0        .0       0        .0
                     3    1         0        .0       0        .0       0        .0
                          7         0        .0       0        .0       0        .0
                          8         0        .0       0        .0       0        .0
                          9         0        .0       0        .0       0        .0
                         10         0        .0       0        .0       0        .0
                         11         0        .0       0        .0       0        .0
                         12         0        .0       0        .0       0        .0
                         13         0        .0       0        .0       0        .0
                         14         0        .0       0        .0       0        .0
              2      1   15         0        .0       0        .0       0        .0
                         16         0        .0       0        .0       0        .0
                         17         0        .0       0        .0       0        .0
                         18         0        .0       0        .0       0        .0
                         19         0        .0       0        .0       0        .0
                         20         0        .0       0        .0       0        .0
                         21         0        .0       0        .0       0        .0
                         22         0        .0       0        .0       0        .0
                     2   15         0        .0       0        .0       0        .0
                         16         0        .0       0        .0       0        .0
                         17         0        .0       0        .0       0        .0
                         18         0        .0       0        .0       0        .0
                         19         0        .0       0        .0       0        .0
                         20         0        .0       0        .0       0        .0
                         21         0        .0       0        .0       0        .0
                         22         0        .0       0        .0       0        .0
                    31   15         0        .0       0        .0       0        .0
                         16         0        .0       0        .0       0        .0
                         17         0        .0       0        .0       0        .0
                         18         0        .0       0        .0       0        .0
                         19         0        .0       0        .0       0        .0
                         20         0        .0       0        .0       0        .0
                         21         0        .0       0        .0       0        .0
                         22         0        .0       0        .0       0        .0
              3      1    0         0        .0       0        .0       0        .0
```

```
ACTIVITY DATA BASE - PART 3
 MINE  VISIT  SHIFT   DAY  HOUR      SEG7   QUANT7      SEG8   QUANT8       SEG9   QUANT9
 ----   ----  -----   ---  ----      ----   ------      ----   ------       ----   ------
 4       3      3       1     1        0        .0        0        .0         0        .0
                              2        0        .0        0        .0         0        .0
                              3        0        .0        0        .0         0        .0
                              4        0        .0        0        .0         0        .0
                              5        0        .0        0        .0         0        .0
                              6        0        .0        0        .0         0        .0
                             23        0        .0        0        .0         0        .0
                       30     0        0        .0        0        .0         0        .0
                              1        0        .0        0        .0         0        .0
                              2        0        .0        0        .0         0        .0
                              3        0        .0        0        .0         0        .0
                              4        0        .0        0        .0         0        .0
                              5        0        .0        0        .0         0        .0
                              6        0        .0        0        .0         0        .0
                             23        0        .0        0        .0         0        .0
                       31     0        0        .0        0        .0         0        .0
                              1        0        .0        0        .0         0        .0
                              2        0        .0        0        .0         0        .0
                              3        0        .0        0        .0         0        .0
                              4        0        .0        0        .0         0        .0
                              5        0        .0        0        .0         0        .0
                              6        0        .0        0        .0         0        .0
                             23        0        .0        0        .0         0        .0
```